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POLLUTION OF THE YELLOWSTONE RIVER AS RELATED TO TASTE AND ODOR PROBLEMS IN MUNICIPAL WATER SUPPLIES IN MONTANA AND NORTH DAKOTA

Public Health Service
Kansas City, Missouri

July 1956

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POLLUTION OF THE YELLOWSTONE RIVER
AS RELATED TO
TASTE AND ODOR PROBLEMS IN MUNICIPAL WATER SUPPLIES
IN MONTANA AND NORTH DAKOTA

A COOPERATIVE FIELD INVESTIGATION

UNDERTAKEN JOINTLY BY

STATE BOARD OF HEALTH HELENA, MONTANA	STATE DEPARTMENT OF HEALTH BISMARCK, NORTH DAKOTA

AND

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
U. S. PUBLIC HEALTH SERVICE
WATER SUPPLY AND WATER POLLUTION CONTROL ACTIVITIES
REGION VI
NOVEMBER 7-13, 1955

JULY 1956

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150

TABLE OF CONTENTS

Page

SUMMARY 1

RECOMMENDATIONS 1

INTRODUCTION 3

PROCEDURES 4

ACKNOWLEDGMENTS 4

DESCRIPTION 5

POLLUTION DISCHARGED 5

PHYSICAL FEATURES 9

  Stream Discharge 9

  Temperature 9

  Turbidity 9

CHEMICAL FEATURES 11

  Oxygen 11

  Hydrogen Ion Concentration 11

  Alkalinity 11

  Nitrogen Cycle 12

  Phosphate 12

  Phenols 12

  Miscellaneous Chemical Features 12

  Discussion of Chemistry 13

BIOLOGICAL FEATURES 13

  Benthic Algae 13

TABLE OF CONTENTS (CONT'D)

Page

Plankton 16

Composition 16

Quantitative Features 18

Larger Bottom Organisms 18

Fishes 21

CARBON FILTER STUDIES 21

DISCUSSION 22

TABLES

Table

1 Daily Municipal Sewage Discharges 6

2 Daily Industrial Waste Discharges 7

3 Industrial Waste Data for 24-hour Composite Samples . . . Following page 8

4 Laboratory Data from Stream Samples " " 8

5 Individual Field Analyses 10

6 Composition of the Microbenthos, August and November 14

7 Composition of Phytoplankton Groups 16

8 Individual Plankton Analyses Following page 18

9 Relative Abundance of Various Benthic Organisms 19

Plate 1 . . . . Following page 5

SUMMARY

Field survey and laboratory results demonstrate heavy pollution and ideal conditions for development of tastes and odors in the Yellowstone and Big Horn Rivers. No taste and odor problem materialized during the period of study that could not be overcome by normal water treatment plant practices, but high potential was clearly apparent.

A summation of major sources of pollution discharged to the various reaches of the stream is shown in Tables 1 and 2. Laboratory data from stream and industrial waste studies are summarized in Tables 3 and 4. Total organic matter, as established by suspended solids, chemical oxygen demand, and 5-day 20° C. B.O.D., demonstrates heavy pollutional discharges to the stream.

Copper, lead and chromium are also present in industrial waste discharges. Amounts do not appear significant, but their presence warrants consideration. Each is toxic in small amounts, with increased emphasis through synergistic action or antagonistic effects on natural biological processes in the stream.

The quantity of phenols entering the river is large. Minute amounts of these materials impart objectionable tastes and odors to water supplies. The phenol producing industries were not all operating at average production rates, and some units were out of operation. The maximum quantity discharged thus could be much greater than recorded during the study. Phenols and related compounds are a critical waste constituent relative to development of tastes and odors. Organic wastes from miscellaneous sources contribute significantly to the over-all problem.

Pollution of the river is so excessive that an immediate and aggressive program of abatement is fully warranted. Adequate waste control can be provided through methods already demonstrated to be effective.

RECOMMENDATIONS

To provide reasonable protection against recurrence of objectionable taste and odor problems at downstream water plants, it is recommended that:

1. All industries undertake an aggressive program to minimize waste losses to sewers and drains by: changes in industrial processes; reclamation of materials now wasted; close operating control to prevent excessive discharges, accidental or otherwise; treatment of residual wastes; and constant monitoring to maintain minimum discharge of pollutional materials.
2. The Underpass Drain at Laurel be relaid of durable materials and constructed to exclude infiltration of oil bearing ground water. This improvement is reportedly already completed.

3. Farmers Union Co-op Exchange, Laurel; Continental Oil Company, Billings; and Carter Oil Company, Billings:

   a. Provide virtual elimination of phenols and related compounds, toxic materials, free and emulsified oils, and floating and settleable solids from oil refinery waste discharges.

   b. Neutralize all caustic or acidic wastes prior to discharge to surface waters.

   c. Surface and supervise loading areas and provide treatment or retention for all wastes and spills from loading operations. Reports subsequent to the study state the loading area has been paved.

   d. Store and handle toxic or other pollutional materials, to be disposed of other than to sewer, so that leaching into underground or surface water be precluded.

4. Great Western Sugar Company, Billings; Holly Sugar Company, Hardin and Sidney, effect:

   Virtual elimination of settleable and floatable solids, and reduce 5-day 20° C. B.O.D. to not more than 8# per ton of beets sliced.

5. The Pierce and the Midland Empire Packing Company, Billings:

   a. Provide effective grease removal.

   b. Effectively screen all wastes except sanitary sewage.

   c. Make appropriate arrangements as necessary for discharge of residual plant wastes to municipal sewers.

6.. The city of Laurel repair breaks in its sewer system to eliminate extraneous unpolluted waters now entering the system.

7. Northern Pacific RR Yards at Laurel effect waste reduction, either by discharge into the Laurel municipal sewer or by the installation of efficient treatment facilities for its own use.

8. The cities of Miles City, Glendive, and Sidney provide effective primary treatment of their sewered wastes.

9. The cities of Hysham, Forsyth, and Hardin enlarge or replace existing facilities to provide efficient treatment.

10. Sewers from the Farmers Union Co-op, the Northern Pacific Railroad, and the Laurel sewage treatment plant each be extended as necessary to discharge directly into the main channel of the river, in order to take maximum advantage of dilution and to prevent accumulation of waste material in secondary river channels.

11. Oil producing fields in the Yellowstone basin be thoroughly investigated and appropriate controls employed to assure that each installation does not constitute a source, or potential source, of pollution from oil and related materials.

12. Each industry and community not now providing adequate control of pollution, prepare a comprehensive plan of pollution control, including a time schedule, and present it to the Montana State Board of Health for formal review and approval or comment. Every effort should be made to advance the program as rapidly as possible in order to reduce the possibilities of taste and odor development.

13. Cooperation and assistance of the Department of Health of Wyoming be sought to obtain treatment of municipal wastes and industrial pollution entering the Big Horn River in Wyoming.

INTRODUCTION

The lower Yellowstone River has developed intermittent conditions, usually in fall or winter, resulting in severe taste and odor problems in municipal water supplies. Difficulties have occurred at Hardin on the Big Horn River, and at Forsyth, Miles City, and Glendive, Montana, on the Yellowstone. Less severe problems have been experienced at Billings. Williston, North Dakota, situated on the Missouri downstream from the Yellowstone, has also encountered difficulties attributed to the Yellowstone. Severity of the problem has varied from conditions amenable to control by modified water treatment procedures to situations beyond the scope of existing treatment facilities.

Surveys designed to inquire into the nature of stream conditions, discharge, pollution, plankton density, etc., promoting unpalatable water quality were conducted cooperatively by the Montana State Board of Health and the U. S. Public Health Service in August and September 1952*. No taste and odor problems occurred that year, but the studies indicated several factors and combinations thereof that could periodically cause trouble. An acute taste and odor problem occurred in 1954 and extended to Williston, North Dakota, on the Missouri River. Complaints arising from this occurrence indicated the necessity of another survey to include quantitative measurement of various waste components discharged to affected streams, more extensive laboratory work, and carbon filter studies. Therefore, a cooperative study involving the State Health Departments of Montana and North Dakota, and the U. S. Public Health Service was initiated on November 5, 1955.

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*A limnological investigation of the Yellowstone River related to taste and odor problems in domestic water supplies, Laurel to Glendive, Montana. August-September 1952.

PROCEDURES

The study was concerned with measurement of various waste components and evaluation of their effects in the lower 360 miles of the Yellowstone and the final 41 miles of the Big Horn River. Engineering evaluations of both the volume and characteristics of the wastes were made from detailed studies of the various processes in all industries contributing appreciable amounts of industrial wastes to both rivers. These were later followed up with actual measurement and analytical determinations on the plant effluents to determine actual contributions. Volume and strength of industrial and municipal wastes were measured by compositing samples according to flow at two-hour intervals over 24-hour periods. Contributing industries were: (1) The Farmers Union Cooperative Exchange Oil Refinery at Laurel; (2) The Continental Oil Company Refinery at Billings; (3) The Carter Oil Refinery below Billings; (4) The Great Western Sugar Company Refinery at Billings; (5) Holly Sugar Company at Hardin; (6) The Holly Sugar Company at Sidney; and (7) The Northern Pacific Railroad Shops at Laurel. Composite samples were taken directly at waste outlets except at the Sidney sugar beet refinery, where they were collected from an irrigation ditch about one mile below the factory, the nearest feasible point for installation of measuring devices. Composites of municipal waste discharges were made at Laurel and Billings. Grab samples were collected at all stream stations. A 24-hour composite for chromium was obtained at the Laurel waterworks intake. Station locations are shown in Plate 1 and analytical data appear in Tables 1, 2, and 3.

Limnological studies were conducted August 24-26 and November 6-13, 1955. The August sampling program was limited to bottom flora and fauna, plankton, temperature and turbidity. In November the above schedule was accompanied by field analyses for pH, alkalinity, oxygen, ammonia and nitrite nitrogen, and phosphate.

Carbon filters were installed at Laurel, Billings, and Forsyth. Those at Billings and at Forsyth accumulated materials contained in river water before and during the sugar beet campaign. A third filter was used at Forsyth after sugar refinery wastes were discontinued. The first filter installed at Laurel was influenced by local wastes brought to the water intake by partial damming resulting from local construction activities. This condition was remedied and a second filter run was assumed representative of normal stream condition. A separate filter was dosed with sugar beet wastes.

ACKNOWLEDGMENTS

The Montana State Board of Health conducted analyses for phenols, copper, and lead, assisted in the sampling program, and supervised installation and shipment of carbon filters. The North Dakota State Department of Health cooperated in the sampling program. The U. S. Public Health Service assumed over-all coordination of the study, industrial evaluations, provided all other analyses, evaluated stream conditions, and developed a final report, following its review in draft form by the State Health

Departments of Montana and North Dakota. Stream flow data were furnished by the U. S. Geological Survey. The city of Billings provided laboratory facilities and parking space for a mobile laboratory and collected some samples. The Carter Oil Company aided in sample collection. Carbon filters were installed and serviced by water operators at Laurel, Billings, and Forsyth. Carbon filter analyses were conducted by Mr. F. M. Middleton, In Charge Organic Contaminants Unit, Robert A. Taft Sanitary Engineering Center. Industrial waste evaluations and reports thereon were completed by Mr. G. N. McDermott, Sanitary Engineer, Robert A. Taft Sanitary Engineering Center. The following individuals participated in the field study: Messrs. Peter Breysse, Engineer, and M. A. Klein, Chemist, Montana State Board of Health; Mr. Joseph Pratschner, Director, Division of Institutional Sanitation, North Dakota State Department of Health; Messrs. C. R. Hirth, Chemist, and P. F. Jones, Engineering Aide, of the Robert A. Taft Sanitary Engineering Center; and Messrs. Paul Bolton and Francis Nelson, Sanitary Engineers, and H. Page Nicholson, Sr. Scienties, Public Health Service, Region VI. Over-all planning and coordination of the study was accomplished by Glen J. Hopkins, Regional Engineer, Public Health Service, Region VI. Biological sections of the report were prepared by Joe K. Neel, Biologist, Public Health Service, Region VI.

The cooperation of all individuals, which often involved long hours of duty and required aggressive interest, was excellent and is gratefully acknowledged.

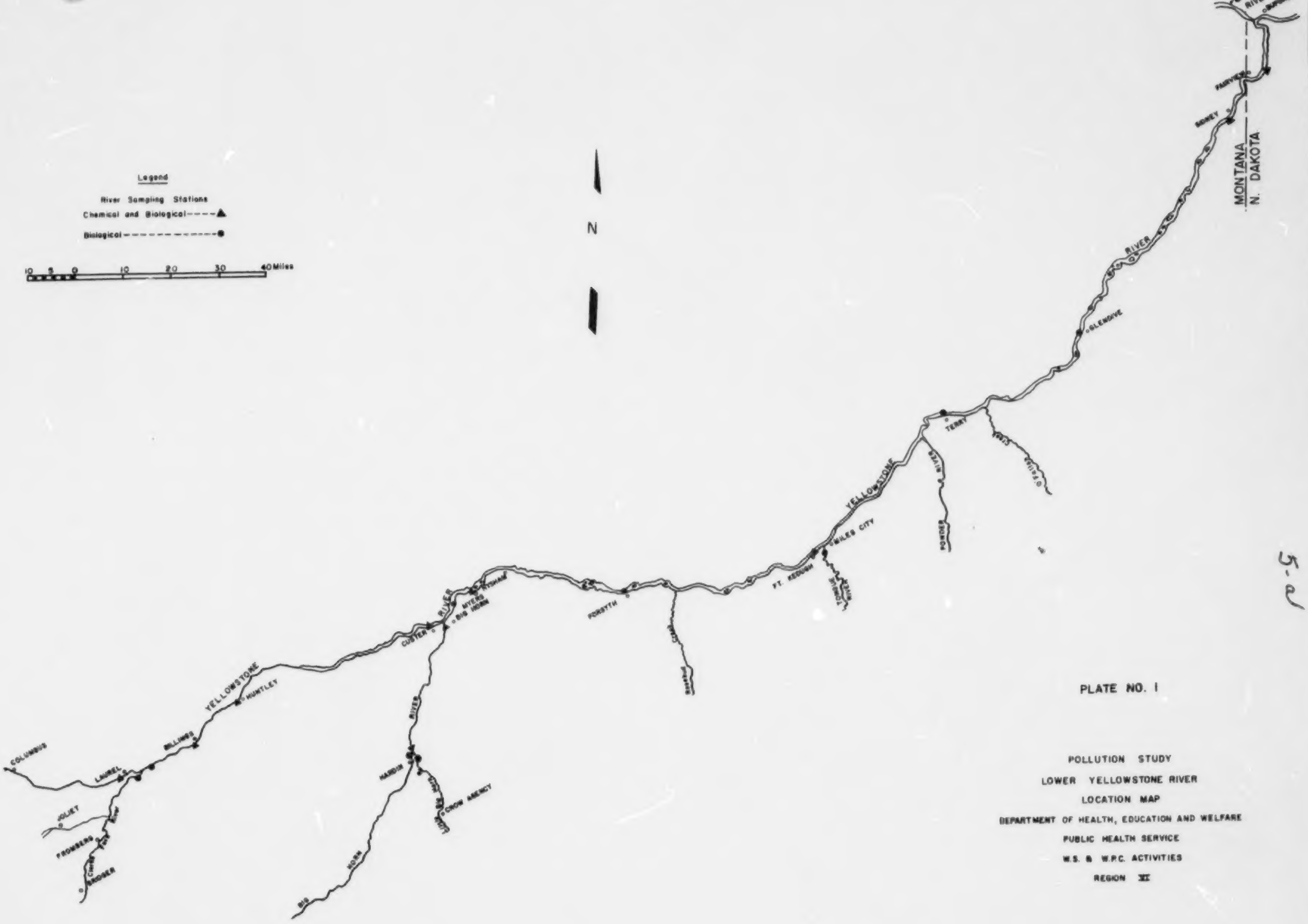
DESCRIPTION

The Yellowstone River (Plate 1) enters the investigated reach as a succession of pools and rapids that gradually merge into a uniform stream below the mouth of the Big Horn. Bottoms in upstream eaches are mainly composed of rock and gravel which are increasingly overlaid by sand and silt in lower stretches. At discharges ranging from 2,000 to 5,000 c.f.s. the river is normally quite clear, except below waste outfalls, down to the mouth of the Big Horn. Turbidity contributed by the Big Horn varies on an annual basis and the river is frequently clear all the way down to a region of intensive irrigation above Sidney. During both periods of study in 1955 it was noticeably turbid in all stretches below the Big Horn. Stream slope is about 7.2 feet per mile over the entire distance.

POLLUTION DISCHARGED

Tables 1 and 2 summarize municipal and industrial waste discharges in the area under investigation. At Laurel, Montana, the Yellowstone receives 5 waste outfalls, 3 carrying oil refinery wastes, one discharging from a railroad shop, and one from the city's primary sewage treatment plant. The oil refinery has only two waste lines but oil contamination of the ground affects a tile drain (Highway Underpass Drain) passing near the plant. This drain, reportedly of open joint construction, empties into the river below the Laurel water plant, often bringing in oil, and continually adding to whitish sulfur bottom deposits. Contributed oil often

5-a



MISSOURI RIVER
BUFORD
MONTANA
N. DAKOTA
FAIRVIEW
SIDNEY
RIVER
GLENDIVE
TERRY
YELLOWSTONE
MILES CITY
FT. KEOGH
TONGUE RIVER
POWDER RIVER
FORSYTH
MYERS
BIG HORN
CUSTER
RIVER
HYSHAM
YELLOWSTONE
HUNTLEY
BILLINGS
LAUREL
COLUMBUS
JOLIET
FROMBERG
BRIDGER
HARDIN
CROW AGENCY
BIG HORN RIVER
Legend
River Sampling Stations
Chemical and Biological----▲
Biological----------●
10 5 0 10 20 30 40 Miles
N

PLATE NO. I

POLLUTION STUDY
LOWER YELLOWSTONE RIVER
LOCATION MAP
DEPARTMENT OF HEALTH, EDUCATION AND WELFARE
PUBLIC HEALTH SERVICE
W.S. & W.P.C. ACTIVITIES
REGION XI

Table 1. Yellowstone River Study - November 1955 - Daily Municipal Sewage Discharges

	Approx. miles above mouth						To Watercourse			
Stream and Municipality	Yellowstone River	Tributary	1950 Population	Population Equivalent (B.O.D.) Untreated Wastes[1]	Treatment Provided	Phenol Pounds	MGD	B.O.D. Pounds	Population Equiv. B.O.D.	Project Needs
Yellowstone River										
Laurel, Mont.	370		3,663	4,000	Primary	.45	.52	268	1,608	None
Billings, Mont.	346		31,834	30,000	Primary	1.75	7.8	2,745	16,470	None
Hysham,* Mont.	260		410	275	Primary	-	-	42	250	E
Forsyth,* Mont.	230.8		1,906	2,000	Primary	-	-	267	1,600	E
Miles City,* Mont.	180.8		9,243	7,235	None	-	-	1,206	7,236	NP
Terry,* Mont.	134.5		1,191	500	Primary	-	-	75	450	None
Glendive,* Mont.	92.1		5,254	5,132	None	-	-	855	5,132	NP
Sidney,* Mont.	30.2		3,987	3,036	None	-	-	506	3,036	NP
Fairview,* Mont.	20		942	1,200	Primary	-	-	160	960	None
Big Horn River	279.4									
Hardin,* Mont.		40.5	2,306	1,800	Primary	-	-	240	1,440	None
Total			60,736	55,178				6,364	38,182	

[1] Includes organic industrial wastes discharging to municipal systems.
*Quantities and strengths estimated.
E - Enlargement of existing plant.
NP - New primary plant.

Table 2. Yellowstone River Study - November 1955 - Daily Industrial Waste Discharges

Stream and Industry	Approx. miles above mouth Yellowstone River	Approx. miles above mouth Tributary	Type of Industry	Type of Waste Produced	MGD	Phenol Pounds	Bio-chemical Oxygen Demand Pounds	Suspended Solids Pounds	Population Equivalent B.O.D.	Population Equivalent S.S.
Yellowstone River										
Hiway Underpass Drain Laurel, Mont.	370.0			Oil refinery wastes	2.2	15.56	147	147	882	735
Farmers Union Co-op Exchange Oil Refinery Laurel, Mont.	370.0		Oil Refinery	Organic & Inorganic	.75	5.85	1,130	474	6,780	2,370
Northern Pac.RR Yd. Laurel, Mont.	370.0		Car Cleaning	Organic & Inorganic	.58	.174	14	633	84	3,165
Gr. Western Sugar Co. Billings, Mont.	346.0		Beet Sugar Refinery	Organic	19.5	2.54	87,100	602,000	522,600	3,010,000
Continental Oil Co. Billings, Mont.	346.0		Oil Refinery	Organic & Inorganic	.14	13.66	732	259	4,392	1,295
*Pierce Packing Co. Billings, Mont.	346.0		Meat Processing	Organic	.36	0	2,520	1,176	15,120	5,580
Midland Empire Pack.Co. Billings, Mont.	346.0		Meat Processing	Organic	.10	0	1,149	607	6,894	3,035
Carter Oil Co. Billings, Mont.	346.0		Oil Refinery	Organic & Inorganic	25.3	244	5,982	7,595	35,892	37,975
Holly Sugar Co. Sidney, Mont.	30.0		Beet Sugar Refinery	Organic	7.2	.18	26,600	216,000	159,600	1,080,000
Big Horn River	279.4									
Holly Sugar Co. Hardin, Mont.		38.0	Beet Sugar Refinery	Organic	4.6	0	23,850	86,500	142,100	432,500
TOTALS					60.73	281.96	149,224	915,391	894,344	4,576,655

*Estimated from Engineering Evaluation.

forms extensive films on the river surface and oil deposits occur along the banks and upon stranded debris. Refinery wastes are discharged directly to two ditches. The upstream ditch, which carries the greater portion of the oil wastes, splits near its lower end and sends part of its discharge directly to the river and the rest to a ditch that receives the lower oil waste line and effluent from the sewage treatment plant. The latter ditch and wastes from the railroad shops enter an isolated channel or slough formed by a chain of three islands near the left riverbank. The slough receives discharge from the main channel above the upper island only when river stages are higher than those noted in November. However, flow from river to slough occurred between the first and second, and second and third islands. The slough discharges into the main channel below the third island. Behind the first island the slough was a quiescent body of dark colored water containing oil and biological growths. The slough became a small rapids, 10 feet wide and 6 inches deep, near the lower end of the first island, and rocks situated therein bore luxuriant algal growths. Sulfur deposits cover a part of the river bottom in that locality and oil slicks often spread out over the main path of flow.

At Billings the river receives: (1) Yegen Ditch, into which are discharged wastes from two meat packing houses, an oil refinery, and a sugar beet plant; (2) the effluent from the city primary sewage treatment plant; and (3) wastes directly from another oil refinery. Pollutants leaving Yegen Ditch flow along the west bank of the river. Sludge beds extend about 100 yards below the mouth of the ditch. Gas bubbles are evolved from the deposits. The ditch discharge was very turbid in November, frequently contained oil and blood, and floating solids tended to accumulate near its mouth. Blood and bits of animal tissue are often present in water passing the bridge on U. S. Highway 87. Dead fish are common in this region. Below this bridge the sewage plant outfall introduces grayish primary effluent, and the lower oil refinery discharges a greenish liquid. Upstream from the lower oil refinery outfall, whitish sulfur deposits covered coarse algal filaments on the bottom. Fragments of these growths collected on screens at the oil refinery water intake and necessitated frequent cleaning.

Sugar beet wastes from the Sidney factory enter an open ditch at the east edge of the plant. This ditch runs southeast to join irrigation drain ditches that flow for some distance before joining the Yellowstone. The Hardin beet plant discharges wastes into a channel of the Big Horn River.

Oil wastes are at times evident over long stretches of the river. In November the odor of refinery wastes was in water at all stations from Billings to Forsyth. In August no such odors were evident at any station on the river. No samples were taken immediately below waste outfalls at that time.

Table 3 summarizes laboratory data relating to waste discharges as obtained by 24-hour composite sampling in November 1955. Table 4 summarizes laboratory data from stream samples collected and analyzed during the study.

8-a

Table 3. Yellowstone River Study - November 1955 - Industrial Waste Data for 24-hour Composite Samples

Sources of Composite	Date	Flow Total MGD	pH Av.	pH Max.	pH Min.	Oxygen Consumed ppm.	B.O.D. ppm.	B.O.D. Pounds	Suspended Solids ppm.	Suspended Solids Pounds	Phenol ppb.	Phenol Pounds	Copper ppm.	Copper Pounds	Total Chromium ppm.	Total Chromium Pounds	Lead ppm.	Lead Pounds	Dissolved Oxygen ppm.	Temperature C° Av.	Temperature C° Max.	Temperature C° Min.	Production Figures	Prod. Fig. Av. Daily	Ratio 5-Day 20° B.O.D. to O.C. %
Laurel - Water Works Intake	Nov. 8-9	1848.0	8.0	8.3	7.6										<0.001	<15.4				6.9	8.0	6.0			
Laurel - Hiway Underpass Drain	Nov. 8-9	2.2	7.5	7.7	7.4	83.0	8.0	147	8.0	147	849	15.56	.02	.367			0.06	1.1	3 p.m. 1.60 7 p.m. 0.60	12.3	13.0	12.0	-		9.6
Laurel - Farmers Union Co-op Exchange Oil Refinery	Nov. 8-9	0.75	7.9	8.4	7.4	294.7	181	1,130	76.0	474	936	5.85	.33	2.06			0.06	.374		35.8	39.0	34.0	13,477 bbls. crude		61.4
Laurel - Northern Pacific R.R. Yard Outfall	Nov. 8-9	0.58	8.2	9.6	7.5	211.3	2.9	14.0	131.0	632.5	36.0	.174	.20	.968	<0.001		0.44	2.12		14.7	16	13	-		1.4
Laurel - Municipal S.T. Plant Outfall - Primary treatment	Nov. 8-9	0.52	7.47	7.5	7.4	232.9	61.7	268	73	316.5	103	.447	.03	.13			.01	.04		17.8	19	17	-		26.4
Billings - G.W. Sugar Co. Effluent	Nov. 8-9	19.5	9.4	10.6	8.2	1095.8	535	87,100	3,700	602,000	15.6	2.54	.01	1.63	T.		.01	1.63		21.8	24	18	3,640 Tons beets sliced	3,650 Tons	48.8
Billings - Continental Oil Co. Refinery	Nov. 8-9	0.14	8.5	8.9	8.2	909.9	627	732	222	259	11,700	13.66	.04	.047	.07	.082	.02	.024		24.7	26	24	10,418 bbls.	10,500 bbls.	69
Billings - Pierce Packing Co. **		0.36						2,520		1,176															
Billings - Midland Empire Packing Co. **		0.10					1376	1,149	730	607															
Billings - Yegen Ditch at Yellowstone River	Nov. 8-9	26.3	8.8	9.6	7.9	790.5	353	72,000	2,290	464,000	112	22.65	.04	8.10	T.		0.10	20.2		14.9	16	14			44.7
Billings - S.T. Plant Eff. Primary treatment	Nov. 8-9	7.8	7.3	7.8	6.8	140.1	42.3	2,745	54	3,500	27	1.75								13.7	15	13.3			30.2
Billings - Carter Oil Ref. Waste Outlet Raw Water Inlet	Nov. 8-9 Nov. 8-9	25.3 25.3	7.1 8.1	8.7 8.6	4.7 5.9	140.1 19.6 120.5	31.7 3.4 28.3	6,700 718 5,982	50 14 36	10,550 2,955 7,595	1,781 630 1,151	377 133 244	- -		<0.001 <0.001 0	<.21 <.21 0	- -			19.9 10.3	21 14	18.5 8.5	18,087 bbls.	20,000 bbls.	22.6 17.3 23.5
Hardin - Holly Sugar Ref. Big Horn River	Nov. 10-11	4.6	>7.8	>9.6	6.0	1643.7	624	23,850	2,260	86,500	0	0	.95	36.3			.09	3.44		27.7	30	25	1,850 tons beets	1,850 tons	37.9
Sidney* - Holly Sugar Refinery	Nov. 10-11	7.2	9.1	9.5	8.0	1056.7	444	26,600	3,600	216,000	3.0	.18	.16	9.6			.02	1.20		17.8	24	13.5	1,961 tons beets sliced		42

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*Sample collected approximately three-fourths mile below waste outlet.

**Estimated from waste evaluation surveys.

Table 4. Yellowstone River Study - November 1955 - Laboratory Data from Stream Samples

Station	Date	Time	pH		°C	Dissolved Oxygen	Oxygen Consumed	5-day 20° C. Biochemical Oxygen Demand		Ratio B.O.D. to O.C.	Copper		Phenol		Lead		Time of River Gauge Reading	Discharge*	Velocity*	River Mile	Time of Flow	
	Nov.		Field	Lab.	Tempera-ture	ppm.	ppm.	ppm.	Pounds	%	ppm.	Pounds	ppb.	Pounds	ppm.	Pounds		c.f.s.	ft. per sec.		Billings to	Hardin to
Laurel - Water Works Intake	7	11:10 A.	7.6	8.1	4.0	12.50	14.9	1.0	16,130	6.7	.01	161.3	1.0	16.1	0.3			3,000				
	9	12:00 M.	8.0	7.9	6.0	12.05	3.9	0.7	10,780	18			0	-				2,860				
	12	10:30 A.	8.1	7.8	2.0	12.55	7.8	0.9		11.6			-					-				
Billings - Water Works Intake	7	1:50 P.	7.7	8.2	5.0	13.50	19.6	1.7	32,500	8.7	.01	191	3.0	57.4	0.01	191	10:15 A.	3,550	2.3	346.0		
	9	4:00 P.	7.7	8.0	5.0	11.65	11.7	1.1	20,060	9.4			5.0	91.5			4:00 P.	3,400	2.3			
	11	4:05 P.	7.8	8.2	2.0	12.65	15.7	0.7	13,400	4.5			0	0.0			4:05 P.	3,550	2.3			
Huntley - Bridge Hiway 10	7	3:20 P.	8.1	8.0	5.0	9.40	23.5	4.6	88,100	19.6	.01	191	9.0	172.0	0.00	0				334.7	0.3 days	
	9	11:00 A.	7.7	7.3	4.0	10.05	27.4	6.1	111,800	22.2			12.0	220.0								
	11	12:45 P.	7.9	7.8	2.0	10.90	23.5	4.5	86,200	19.1			35.0	670.0								
Custer - Bridge State Hiway 47	7	2:00 P.	8.1	8.1	5.0	12.30	13.7	3.0	57,400	21.9	.005	96	1.5	28.7	0.01	191						
	9	1:25 P.	8.1	7.9	5.0	11.35	17.6	2.5	45,800	14.2			1.5	27.4								
	11	9:50 A.	8.1	7.9	3.0	7.40	17.6	2.3	44,000	13.1			6.0	115.0						294.4	1.73 days	1.0 days
Big Horn enters Yellowstone R. between Custer and Myers																						
Myers - Bridge State Hiway	7	12:10 P.	7.4	8.0	3.5	11.10	29.4	2.2	75,000	7.5	.01	340	1.5	51.0	0.02	680		6,320c				
	9	12:15 P.	8.1	7.8	4.0	10.85	19.6	3.5	110,500	17.9			1.5	47.0				5,950c				
	11	11:00 A.	7.9	7.9	2.0	8.55	19.6	3.2	107,200	16.3			5.0	168.0				6,230c				
Miles City - Water Works Intake	7		7.4	8.3	3.2	12.60	21.5	1.9	67,500	8.8			1.5	53.0			2:00 P.	6,590	2.35	178.5	4.3 days	3.6 days
	9			7.9		12.05	13.7	4.9	176,500	35.8			0	0			12:00 N.	6,690	2.35			
	11	11:50 A.	7.7	8.0	3.0	11.80	19.6	1.5	48,100	7.7			2.0	64.0			12:00 N.	5,950	2.35			
Sidney - Bridge State Hiway 235	7		7.6	8.1	0.5	13.10	38.2	2.2	68,500	6.3			3.0	92.8				5,770		30.2	8.2 days	7.5 days
	9			8.0		12.45	15.7	3.2	75,700	20.4			1.5	35.8				4,440				
	11	5:45 A.	7.8	8.0	1.0	11.65	25.4	1.0	34,600	3.9			0	0				6,440				
Cartwright - N.D. State Hiway 23	7	6:45 A.	7.6	8.2	0.5	13.10	43.0	3.4	105,500	7.9			3.0	92.8								
	9			8.0		12.15	15.7	3.2	75,700	20.4			4.0	95.6								
	11	6:45 A.	8.0	7.9	1.0	11.90	29.4	4.0	138,400	13.6			0	0								
Hardin - Beet Sugar Plant H_2O Intake Big Horn River	7	10:10 A.	7.5	7.9	3.5	11.75	33.3	2.6	37,200	7.8	.00	0	1.5	22.0	0.02	287	10:10 A.	2,660	2.5			
	9	2:30 P.	8.1	8.1	5.0	11.75	19.6	2.8	37,100	14.3			0	0			2:30 P.	2,460	2.5			
	11	5:30 A.	8.3	8.3	1.0	8.55	25.4	2.6	33,600	10.2			6.0	78.0			5:30 A.	2,400	2.5			
Big Horn - Bridge Hiway 10 Big Horn River	7	1:10 P.	7.8	8.1	4.0	11.40	31.3	4.8	63,600	15.3	.015	200	1.5	20.0	0.04	531	1:10 P.	2,460	2.5	Little B.H. 40 mi.		
	9	12:50 P.	8.1	8.2	5.0	10.60	25.4	4.0	53,100	15.7			0	0			12:50 P.	2,460	2.5			
	11	10:20 A.	8.0	7.9	2.0	11.25	23.5	1.9	24,210	8.1			4.0	51.0			10:20 A.	2,370	2.5			

*Information obtained from U.S.G.S.

c - Calculated Yellowstone ≠ Big Horn.

8-b

PHYSICAL FEATURES

Stream Discharge

Yellowstone discharge at Billings, Montana, varied from 3,400 to 3,550 cubic feet per second during the sampling period. Five-year minimum expected flows are 2,274 c.f.s. in summer and 1,587 c.f.s. in winter. At Miles City, Montana, flow varied from 5,950 to 6,690 c.f.s. There, five-year minimum expected flows are predicted at 3,693 c.f.s. in summer and 2,487 c.f.s. in winter. At Sidney, Montana, minimum flows expected to occur once in five years are lower than those predicted at Miles City. Twenty daily flow records during November and December 1955 show discharges from 1,080 to 4,690 c.f.s.at Billings.

Flow in the Big Horn during the sampling period varied from 2,370 to 2,660 c.f.s. at two sampling stations. The five-year minimum expected flows at the gauging station near St. Xavier, Montana, are 1,350 c.f.s. and 1,124 c.f.s. for summer and winter, respectively.

It is evident that the study was made during river stages averaging well above critical levels expected to occur as frequently as once in five years.

Temperature

The range of temperature variation (Tables 4 and 5) was usual for the seasons represented. Temperatures as low as those noted in November are antagonistic to rapid oxidation of those pollutants amenable to biochemical action. Slower oxidative rate will allow waste components to extend over greater stream distances and be more concentrated at any location. Hence, such substances as phenols may occur in objectionable concentrations during cold weather.

Turbidity

Turbidity maximums were considerably greater in August (Table 5), yet stretches of the river that were slightly turbid in November were clear in August. In August, turbidity measurable by the Jackson method occurred only in the Big Horn and in the Yellowstone below entrance of this tributary. Decline at the first two downstream stations indicated dilution of muddy water brought in by the Big Horn and suggested that the latter stream was the only significant source of suspended matter upstream from Miles City. Big Horn River discharge occasioned a similar turbidity increase in November, at which time measurable turbidity, apparently resulting from beet sugar wastes at Billings, existed in the Yellowstone above the Big Horn. Turbidity increase at Glendive in August could have resulted from inflow of the Tongue and/or Powder Rivers. Turbidity was below the range of a Jackson turbidimeter at all stations except the Big Horn River when similar surveys were conducted in August and September 1952.

Table 5. Yellowstone River Study - Individual Field Analyses

Station	Temperature °C. Aug.	Temperature °C. Nov.	Turbidity ppm Aug.	Turbidity ppm Nov.	November only pH	CO_3 Alk. ppm	HCO_3 Alk. ppm	Oxygen % Sat.	NH_3 ppm	NO_2 ppm	PO_4 ppm
Yellowstone R. above Laurel	19.5	4	< 20	< 20	8.1	10	102	103.2	0.1	0	0
Yellowstone R. 1 mi. below Laurel		6.5		< 35	8.0	2	128		1.2	0.02	< 2
Clarks Fork R. near mouth	20	2.5	< 20	64	8.2	14	186	92.8	0.15	0	0
Yellowstone R. 3 mi. below Laurel		5		< 35	8.0	4	116	92	0.1	0.01	0
Yellowstone R. below Yegen Ditch		13.5		230	8.4	-	< 284	43	2.4	0.07	0
Yellowstone R. Hwy 87 Bridge below Billings		6	< 20	< 35	8.2	12	126	101	0.1	0	0
Yellowstone R. near Huntley	24	5	< 20	42	8.0	6	140	84.2	0.1	0.005	0
Yellowstone R. near Custer	25	1	< 20	32	8.2	8	138	93.5	0.1	0.005	0
Big Horn R. near Hardin	25	1.5	390	192	8.2	16	191	89.2	0.01	0.005	0
Little Big Horn near mouth		1.5		< 35	8.2	14	201	96.0	0.1	0	0
Big Horn R. near Big Horn	25	2	480	131	8.2	16	191	95.9	0.1	0.005	0
Yellowstone R. at Myers	25	0	240	137	8.2	8	170			0.005	
Yellowstone R. at Forsyth	26	0	140	77	8.2	10	163	90.5	0.1	0.005	0
Yellowstone R. at Ft. Keough	25	0	160	72	8.2	10	175	89.8	0.1	0.01	0
Tongue R. near mouth		0		102	8.2	12	261	89.8	0.1	0	0
Yellowstone R. near Terry		0		60	8.2	10	177	95.4	0.1	0.005	0
Yellowstone R. at Glendive	25	0	1,000	135	8.2	10	183	94.8	0.1	0.005	0
Yellowstone R. above Sidney	25	0	220	105	8.2	12	191	94.2	0.1	0.005	0
Yellowstone R. near Cartwright	25	0	150	84	8.2	12	196	94.2	0.1	0.005	0
In Yegen's Ditch		16						18.1			

CHEMICAL FEATURES

Oxygen

Supersaturation occurred everywhere, including Clarks Fork, the Big Horn and Tongue Rivers, in 1952. In November 1955, supersaturation was evident only above Laurel (Table 5) and at Highway 87 Bridge in Billings. Samples taken in conjunction with the laboratory survey (Table 4) showed supersaturation above Laurel, at the Billings water intake, and, once in three samples, at Custer, Miles City, and in the Big Horn at Hardin. Saturation varied from around 85 to 95 percent, although the small area of the river affected by Yegen Ditch was only 43 percent of saturation. Oxygen concentration was well above minimums required for desirable aquatic life.

Oil refinery wastes appeared equally abundant at outfalls in 1952 and 1955, but their odor never carried as far as Huntley in 1952.

Oxygen consumed and 5-day 20° C. biochemical oxygen demand were low in ppm, eliminating them from critical items relative to taste and odor problems other than possible synergistic effects.

Hydrogen Ion Concentration

The normal pH level in the Yellowstone River apparently is around 8.2. This value prevailed in November 1955. The discharge from Yegen Ditch raised pH to 8.4 for a short distance along the west river bank. Organic pollution apparently reduced pH below Laurel and at Huntley (Table 5). In 1952, pH varied from 8.3 to 8.7.

Hydrogen ion concentration (Table 4) at all river sampling stations was well within a normal pH range. The range noted is satisfactory for biological activity.

Alkalinity

Monocarbonate present in 1955 (Table 5) was apparently a soluble form (Na_2CO_3 or K_2CO_3) originating in soil drainage. In restricted localities, etc., above Laurel, or at U. S. Highway 87 Bridge, some calcium monocarbonate was added by photosynthesis. The normal CO_3 concentration for the Yellowstone appears to be 10-12 ppm. Concentration in the Big Horn and Clarks Fork exceeded this level by 2 to 4 ppm. Carbon dioxide or other acids contained in wastes contributed at Laurel and Billings reduced CO_3 in the main stem all the way down to the region of Myers Bridge. In 1952, CO_3 concentration ranged from 10 to 30 ppm in the Yellowstone, from 8 to 30 ppm in Clarks Fork, and from 14 to 30 ppm in the Big Horn.

In general, bicarbonate exhibited the downstream increase that characterizes rivers when a large part of flow accretion originates in ground water discharge. In 1952 maximum bicarbonate alkalinity (150 ppm) occurred just below Billings. This value exceeded levels noted up and downstream from that point and was assumed to result from waste discharges.

At Glendive the 1952 HCO_3 concentration was 130 ppm or 53 ppm less than that found in 1955. Lower bicarbonate in 1952 bespoke the photosynthetic influences of a denser and more widespread algal population.

Nitrogen Cycle

Nitrite nitrogen (Table 5) indicated the entrance of organic pollution at Laurel and Billings and smaller downstream communities. In August 1952, nitrite occurred at all stations below Billings, but in September 1952, it disappeared below Forsyth. In colder weather nitrification may be slowed sufficiently to permit nitrite production from Billings wastes in remote downstream reaches. Normal concentration of ammonia nitrogen appeared to be 0.1 ppm. In 1952 ammonia concentration ranged from 0.5 to 1.1 ppm, the larger amounts occurring below Laurel, below Billings, in the Big Horn River, at Miles City, in the Powder River, and at Terry. Increases in ppm were not always associated with local waste discharges.

Phosphate

Phosphate was found only at the river's junction with the slough that carries part of Laurel's waste load. In 1952, it was found everywhere except near Miles City, and was assumed to originate in underground phosphate bearing strata that have been described for several areas in the upper Yellowstone Basin. Constant additions would have been required to maintain the noted concentration (1-3 ppm) in the presence of luxuriant algal growths.

Phenols

Phenolic compounds occurred at all river stations at least once during the 1955 survey (Table 4). Highest concentrations were at Huntley, about 10 river miles below Billings. One ppb was found at the Laurel water intake November 7. As indicated earlier, phenols are considered unusual there, and their rare appearance may be explained by construction activities that disrupted normal flow into the intake. Waste discharges putting considerable amounts of phenols into the river were the Highway Underpass Drain at Laurel, and Yegen Ditch at Billings (Table 3). The major portion of phenols in Yegen Ditch appear to originate in the Continental Oil Refinery.

Some tastes and odors that have occurred in water supplies have been described as medicinal or phenolic. It is known that minute quantities of phenols will render water unpalatable. Quantities wasted to the Yellowstone River are adequate to occasion taste and odor difficulties during certain river conditions. They may be expected to have their major influence during cold weather, when biochemical oxidation is at or near its annual minimum.

Miscellaneous Chemical Features

Copper, lead, and chromium appeared in industrial waste discharges (Table 3). Concentrations, however, were quite low, and their individual or synergistic effect upon stream biota were probably inconsequential Copper concentration was insufficient to markedly interfere with biological destruction of phenolic compounds. Concentration of copper, lead, and chromium at various stream stations appears in Table 4.

Discussion of Chemistry

While biochemical oxygen demand was too low to materially affect stream oxygen levels, compounds furnishing B.O.D. are conducive to snyergistic actions. Wastes contributed contain various substances, which, while not directly involved in tastes and odors, may stimulate growth of algae and other organisms to nuisance levels.

Minute quantities of phenol are capable of producing objectionable flavors in water supplies, and this pollutant is a critical one. As industries producing the major amounts of phenol were not all operating at full capacity, the quantities noted are lower than the maximum probable discharges to the stream. This fact emphasizes the likelihood of phenolic involvement in taste and odor problems. "Slug" releases, or discharge alterations resulting from changes in stream flow, may place critical concentrations of phenols at various water intakes.

Other pollutants (Table 3) are discharged in sufficient quantity to initiate or assist in taste and odor development during critical stream condition. It should be emphasized that 24-hour composite samples do not show fluctuations in quality or quantity of wastes that occur over short periods of time. The total poundage of waste organic matter (based upon B.O.D.) places a heavy load on the stream. Delayed waste effects may originate in decomposition of sludge beds or in the disintegration and the downstream movement of these beds occasioned by changes in stream flow.

BIOLOGICAL FEATURES

Benthic Algae

In August bottom algal growths consisted largely of gelatinous diatom films that were present at all localities sampled but most luxuriant in stretches with rocky bottoms. A branched filamentous green alga, Cladophora, occurred, heavily invested with diatoms, above Laurel and at the abandoned old South Road Bridge at Billings. Tetraspora, a green alga forming gelatinous masses, accounted for a significant portion of the algal bottom film at Forsyth. Diatoms were the dominant growth at all other localities, although their thin layers and general brownish color usually made them inconspicuous. In the Big Horn at Hardin a large celled diatom, Biddulphia, formed extensive green mats with floating strands. Diatom layers usually contained filamentous blue-green algae and small green algae, Cosmarium, Gloeocystis, etc. All benthic growths except larger filamentous algae contributed displaced individuals to the river plankton.

River ice appeared during the November survey period and precluded sampling or observation of bottom flora in the lower Big Horn or in the Yellowstone below Custer. In stretches where study was possible, diatoms were still present but their assemblages had been invaded by various green algae that usually formed the bulk of the benthic growth. The most abundant alga *Cladophora*, was dominant in Clarks Fork, in the Little Big Horn near Hardin, and at most localities in the Yellowstone from above Laurel to Custer. Below oil refinery outfalls at Laurel and above the lower refinery at Billings, *Cladophora* growths were short and dense and heavily covered with tightly adhering sulfur deposits. At the junction of the Laurel slough and the river, *Cladophora* was largely replaced by *Spirogyra* and *Stigeoclonium*, both filamentous green algae. Screens on the Billings water intake were densely overgrown with *Cladophora*.

Drains and ditches conveying wastes from Laurel and Billings frequently supported benthic growths at their outfalls or along their bottoms. The Highway Underpass Drain at Laurel, although often discharging oil, had a dense blanket of algae on rocks receiving its outfall. The most numerous organism was *Chlamydomonas*, a unicellular green flatellate, but also present was a varied group of diatoms and *Spirogyra*. The ditch receiving the upper oil refinery outfall had a sparse *Chlamydomonas* growth on its bottom. The ditch carrying railroad shop wastes had a very luxuriant crop of *Stigeoclonium* and *Cladophora*, which contained several diatoms and filaments of *Ulothrix*, two species of the green flagellate *Euglena*, and diatoms of the *Synedra* gr. The common sewage fungus, *Sphaerotilus*, occurred in discharge from the Highway Underpass Drain at Laurel and below Yegen Ditch at Billings.

Composition of algal growths and associated microscopic animals appears in Table 6. In August green algae were largely represented by unicellular or globose colonial species but filamentous green forms were more numerous in November. The diatom flora exhibited few seasonal differences.

Table 6. *Composition of the Microbenthos, August and November*

GREEN ALGAE

Chlamydomonas gr.

Gloeocystis gigas (Aug.only)

Gloeocystis vesiculosa (Aug. only)

Tetraspora lubrica (Aug. only)

Ulothrix sp. (Nov. only)

Stigeoclonium sp. (Nov. only)

Cladophora sp.

Pediastrum duplex (Aug. only)
Pediastrum Boryanum (Aug. only)
Closteriopsis longissima (Aug. only)

Scenedesmus bijuga

Scenedesmus dimorphus

Scenedesmus quadricauda (Nov. only)

Dictyosphaerium pulchellum (Aug. only)

Schroederia setigera (Aug. only)

Coelastrum sphaericum (Aug. only)

Ankistrodesmus falcatus (Aug. only)

Actinastrum Hantzschii (Aug. only)

Vaucheria sp. (Nov. only)

Spirogyra sp. (Nov. only)

Cosmarium sp.

Closterium sp. (Aug only)

Table 6. Composition of the Microbenthos, August and November--(Cont'd)

EUGLENOPHYTA

- *Euglena Ehrenbergii*
- *Euglena* spp.

DIATOMS

- *Melosira granulata* (Aug. only)
- *Melosira* sp.
- *Stephanodiscus astraea* (Aug. only)
- *Cyclotella-Stephanodiscus* gr.
- *Biddulphia laevis* (Aug. only)
- *Rhizosolenia* gr.
- *Diatoma vulgare*
- *Fragilaria* spp.
- *Synedra* gr.
- *Cocconeis placentula*
- *Rhoicosphenia curvata* (Nov. only)
- *Gyrosigma* gr.
- *Navicula* gr.
- *Pinnularia* sp.
- *Cymbella* spp.
- *Gomphonema* spp.
- *Amphora* sp. (Nov. only)
- *Cystopleura* spp.
- *Rhopalodia gibba* (Nov. only)
- *Nitzschia sigmoidea*
- *Nitzschia* sp.

DIATOMS (Cont'd)

- *Cymatopleura solea*
- *Surirella* spp.

BLUE GREEN ALGAE

- *Merismopedia* punctata (Nov. only)
- *Phormidum* spp. (included in Oscillatoria gr. in plankton)

FUNGI

- *Sphaerotilus* sp. (Nov. only)

PROTOZOA

- *Centropyxis aculeata* (Aug. only)
- *Euglypha alveolata*
- *Lionotus* sp. (Nov. only)
- *Paramecium putrinum* (Nov. only)
- *Frontonia* sp. (Aug. only)

ROTIFERS

- *Philodina* sp.
- *Lecane* sp. (Nov. only)

NEMATODES

- Nematoda spp.

ANNELIDA

- Naididae
- Tubificidae

COPEPODA

- Hartpacticoidea (Aug. only)

Plankton

Composition

A similarity in the makeup of plankton and benthic algal growths may be noted by reference to Tables 6 and 7. The majority of algae present occurred in both situations, but the most numerous groups found in both plankton and benthos are normally bottom dwellers. The phytoplankton was therefore largely composed of displaced benthic algae, but true plankters were present, and several forms that normally live as plankters were actively growing amid the attached algae. Certain groups, eg. *Chlamydomonas* and *Euglena* may grow in great abundance either attached or free floating, so in many instances it is not possible to definitely determine points of origin. Many smaller benthic forms, single diatom cells, etc., have the ability to survive long stream distances when brought into suspension.

In both August and November displaced benthic diatoms formed the bulk of the plankton population. In August unicellular and minute colonial green algae made up a significant portion of the plankton in the Yellowstone below Billings but were poorly represented in November, when the population, with the exception of two stations, consisted almost exclusively of diatoms. True plankters and forms occurring in both plankton and benthos are differentiated in Table 8. The majority of green algae placed in the second group more commonly occur as plankters, but most diatoms in that category are benthic forms that were brought into suspension.

In general, waste discharges little affected plankton composition, as the population was largely one that would occur in streams receiving little or no pollution. However, certain forms were introduced by waste discharges and others were stimulated by materials contained in or produced from the various wastes.

At magnifications used for counting plankters it is not possible to identify many forms to species. Forms with much the same appearance were therefore lumped into various easily recognizable groups. Composition of the various categories appears in Table 7.

Table 7. *Composition of phytoplankton groups*

- Chlamydomonas gr.
  - *Chlamydomonas* sp.
  - *Carteria* sp.
- Gloeocystis spp.
  - *Gloeocystis gigas*
  - *Gloeocystis vesiculosa*
- Cyclotella-Stephanodiscus gr.
  - *Cyclotella bodanica*
  - *Stephanodiscus astraea* minutula
- Rhizosolenia gr.
  - *Rhizosolenia*
  - *Nitzschia* sp.

Table 7. *Composition of phytoplankton groups*-(Cont'd)

- Fragiloria spp.
  - *Diatoma anceps*
  - *Fragilaria* spp.
- Synedra gr.
  - *Synedra ulna*
  - *Synedra ulna* var. *amphirhynchus*
  - *Synedra ulna* var. *oxyrhynchus*
  - *Synedra ulna* var. *Ramesi*
  - *Synedra ulna* var. *aequalis*
- Gyrosigma gr.
  - *Pleurosigma delicatulum*
  - *Gyrosigma* sp.
- Navicula gr.
  - *Synedra Vaucheriae*
  - *Navicula lanceolata*
  - *Navicula scutum*
  - *Navicula cuspidata* var. *ambigua*
  - *Navicula radiosa*
  - *Navicula pupula*
  - *Caloneis amphisbaena*
  - *Nitzschia dissipata*
- Cymbella spp.
  - *Cymbella affinis*
  - *Cymbella prostrata*
- Cymbella spp. (cont'd)
  - *Cymbella pusilla*
  - *Cymbella tumida*
  - *Cymbella turgida*
  - *Cymbella parva*
  - *Cymbella lanceolata*
  - *Cymbella aspera*
- Gomphonema spp.
  - *Gomphonema olivaceum*
  - *Gomphonema lanceolatum*
  - *Gomphonema* sp.
- Cystopleura spp.
  - *Cystopleura intermedia*
  - *Cystopleura sorex*
- Nitzschia gr.
  - *Nitzschia sigmoidea*
  - *Nitzschia spectabiles*
- Surirella spp.
  - *Surirella ovata*
  - *Surirella ovalis*
- Oscillatoria gr.
  - *Oscillatoria* spp.
  - *Phormidium* spp.

Quantitative Features

Plankton density (Table 8) varied with river location. August and November 1955 samples that covered the same river reach show a different pattern of high and low densities. In August greatest concentration occurred at Forsyth, slightly lesser numbers were evident at Miles City and Sidney, and the minimum density was found at Glendive. Plankton maximums occurred farther upstream in November. In the stretch below Billings highest concentration was at Custer, a decline characterized the stretch from Forsyth to Miles City, another increase was evident from Terry to Glendive, and lowest concentrations occurred at Sidney and Cartwright. Above Billings plankton was densest three miles below Laurel. Its numbers diminished progressively downstream to the lower oil refinery outfall at Billings, but started upward again at Huntley.

Plankton increases below Laurel and Billings, which were also evident in 1952, apparently resulted from nutrients in waste discharges. Some oxidation and dispersion of wastes generally occurs before a native algal population is stimulated. Warmer weather induces such changes at a more rapid rate, and plankton increases occur nearer waste sources. This was not the case in 1955, when plankton increases occurred nearer to pollution discharges in colder weather. However, the majority of organisms involved in plankton increases were displaced bottom forms and floating ice could have modified the usual course of bottom erosion or interfered with discharge, etc. Limited available data reduce inquiry into such probable factors to speculation, and further comment is unwarranted. Seasonal shifts in location of plankton maximums do not belittle the role of waste products as causative agents.

Algal upswings below major waste outfalls were noted in 1952. Lesser increases have usually resulted from pollutional influences in the reach from Miles City to Glendive. The August 1955 plankton depression at Glendive coincided with a marked turbidity elevation. Factors associated with plankton growth in lower reaches of the Yellowstone are sometimes obscured by dense populations introduced from the Big Horn River.

Algal upsurges resulting from nutrients contained in waste discharges are followed by downstream slumps after the added materials are exhausted. The pattern of rising and falling algal densities below sources of pollution in the Yellowstone represents a typical reaction of stream plankton to waste discharges.

Larger Bottom Organisms

Composition and relative abundance of macroscopic benthic organisms at localities sampled appear in Table 9. As in 1952, no bottom organisms occurred in the first 11 miles below waste outfalls at Billings. Wastes discharged at Laurel eliminated all forms except sludge worms and snails at the entrance of the slough and two miles downstream. With the exception of tubificids one mile below Laurel, bottom organisms were nowhere abundant, and the majority of groups were represented by few specimens.

Table 8. Yellowstone River Study - Individual Plankton Analyses - August and November 1955

	Y. 366 Elev. 3260 Yellowstone R. above Laurel		Y. 364 Elev. 3240 Yellowstone R. 1 mi. below Laurel	Y. 363.7 C.F. 0.3 Elev. 3230 Clarks Fork Near Mouth		Y. 362 Elev. 3210 Yellowstone R. 3 mi. below Laurel	Y. 349 Elev. 3100 Yellowstone R. Above Billings	Y. 346 Elev. 3070 Yellowstone R. Below Yegen Drain	Y. 345.8 Elev. 3070 Yellowstone R. U.S. Hwy. 87 Crossing Billings
	8/25	11/9	11/10	8/25	11/9	11/10	8/25	11/7	11/10
PHYTOPLANKTON									
GREEN ALGAE									
Chlamydomonas gr.[3]							1		
Coccomonas[1]									
Gloeocystis spp.[3]									
Tetraspora sp.[3]									
Sphaerocystis Schroeteri[1]									
Pediastrum duplex[3]									
Pediastrum boryanum[3]		1							
Coelastrum sphaericum[3]									
Dictyosphaerium pulchellum[3]									
Ankistrodesmus falcatus[3]									
Scenedesmus bijuga[3]									
Scenedesmus dimorphus[3]									
Scenedesmus quadricauda[3]									
Schroederia setigera[3]				5					
Oocystis sp.[1]	1								
Closteriopsis longissima[3]									
Actinastrum Hantzschii[3]									
Crucigenia rectangularis[1]									
Closterium sp.[3]									
Cosmarium sp.[3]	6						6		
EUGLENOPHYTA									
Euglena spp.[3]			51		1				
Trachelomonas sp.[1]							1		
DINOPHYCEAE									
Pleurodinium sp.[1]									
DIATOMS									
Melosira granulata[3]	1								
Melosira granulata angustissima[1]	2	2							
Cyclotella-Stephanodiscus gr.[3]	8			24		1	14	2	
Stephanodiscus astraea[3]	7								
Biddulphia laevis[3]									
Rhizosolenia gr.[3]	6	2	1	173	2	11	4		17
Fragilaria crotonensis[1]							4		
Fragilaria spp.[3]									
Diatoma vulgare[3]	1	4	97		43	468		9	183
Rhoicosphenia curvata[3]									
Synedra gr.[3]		49	97	11	304	144		25	130
Asterionella formosa[1]									
Cocconeis placentula[3]			2	4		1	19		
Gyrosigma gr.[3]					12	1	2		
Navicula gr.[3]	43	17	48	268	127	47	132	8	52
Pinnularia sp.[3]									
Amphora veneta[3]						4			4
Gomphonema spp.[3]	3	10	16	14	8	13	13		20
Cymbella spp.[3]		11	27	14	14	37	10		14
Cystopleura spp.[3]	90	20	31			5	26		
Rhopalodia gibba[3]									
Nitzschia gr.[3]	13			18			15		
Surirella spp.[3]									
BLUE-GREEN ALGAE									
Gomphosphaeria aponina[1]									
Dactylococcopsis sp.[1]									
Oscillatoria gr.[3]			106						
Anabaena sp.[1]									
Aphanizomenon flos-aquae[1]									
ZOOPLANKTON									
PROTOZOA									
Paramecium putrinum[3]			1					25	
Lionotus sp.[3]									
Strombilidium sp.[1]									
Vorticella campanula[3]									
ROTIFERS									
Lecane lunata[3]					1				
Mytilina ventralis[1]									
NEMATODA									
Nematoda sp.[3]									
TOTAL	181	116	477	531	512	732	247	69	420

1 - Occurred in plankton only.
3 - Occurred in plankton and benthos.

Table 8. Yellowstone River Study - Individual Plankton Analyses - August and November 1955--Continued

	Y. 364 Elev. 3060 Yellowstone R. Below Carter Refinery outlet	Y. 334.7 Elev. 3000 Yellowstone R. Near Huntley		Y. 284.6 Elev. 2710 Yellowstone R. Near Custer		Y. 279.4 B.H. 40.5 Elev. 2880 Big Horn R. Above Hardin		Y. 279.4, B.H. 40 L.B.H. 1 Elev. 2890 Little Big Horn R. Near Mouth	Y.279.4 B.H. 2 Elev. 2680 Big Horn R. Near Big Horn		Y. 268.7 Elev. 2630 Yellowstone R. Near Myers	
	11/6	8/25	11/10	8/25	11/11	8/24	11/11	11/11	8/25	11/11	8/25	11/12
PHYTOPLANKTON												
GREEN ALGAE												
Chlamydomonas gr.[3]				43				3				
Coccomonas[1]									2			
Gloeocystis spp.[3]		1		1		12				4	12	
Tetraspora sp.[3]					193							
Sphaerocystis schroeteri[1]												
Pediastrum duplex[3]												
Pediastrum boryanum[3]												
Coelastrum sphaericum[3]												
Dictyosphaerium pulchellum[3]												
Ankistrodesmus falcatus[3]												
Scenedesmus bijuga[3]						2						
Scenedesmus dimorphus[3]				1								
Scenedesmus quadricauda[3]		2		4						1		
Schroederia setigera[3]				1								
Oocystis sp.[1]												
Closteriopsis longissima[3]									6		2	
Actinastrum Hantzschii[3]											4	
Crucigenia rectangularis[1]				1		2						
Closterium sp.[3]							1					
Cosmarium sp.[3]		17		17			1				1	
EUGLENOPHYTA												
Euglena spp.[3]		2		4	284							
Trachelomonas sp.[1]												
DINOPHYCEAE												
Pleurodinium sp.[1]												
DIATOMS												
Melosira granulata[3]	1						3					1
Melosira granulata angustissima[1]										1		
Cyclotella-Stephanodiscus gr.[3]		12		188		6		1	4	1	54	2
Stephanodiscus astraea[3]		2					6			8	2	
Biddulphia laevis[3]												
Rhizosolenia gr.[3]	1	10	4	28	1	43	7		54	6	80	4
Fragilaria crotonensis[1]		3		1			1		2	2	1	
Fragilaria spp.[3]							2					2
Diatoma vulgare[3]	88	16	92	1	104		40			3		103
Rhoicosphenia curvata[3]	1											
Synedra gr.[3]	111		137		73		25	6		12		132
Asterionella formosa[1]										1		2
Cocconeis placentula[3]		6	4	6			4			2		2
Gyrosigma gr.[3]	1		7	13	4		2			8	9	2
Navicula gr.[3]	58	172	67	50	69	56	182	4	22	145	53	234
Pinnularia sp.[3]			2									
Amphora veneta[3]	2											
Gomphonema spp.[3]		10	10		4		8			3		1
Cymbella spp.[3]	6	11	27	4	20		2	2			2	10
Cystopleura spp.[3]	2	42	14	2			1	1			4	
Rhopalodia gibba[3]			2					1				
Nitzschia gr.[3]		29		14		16			5		88	
Surirella spp.[3]										4		
BLUE-GREEN ALGAE												
Gomphosphaeria aponina[1]												
Dactylococcopsis sp.[1]												
Oscillatoria gr.[3]		1	1		1				4			16
Anabaena sp.[1]				1								
Aphanizomenon flos-aquae[1]												
ZOOPLANKTON												
PROTOZOA												
Paramecium putrinum[3]												
Lionotus sp.[3]					1							
Strombilidium sp.[1]		2		2								
Vorticella campanula[3]					2							
ROTIFERS												
Lecane lunata[3]												
Mytilina ventralis[1]					1							
NEMATODA												
Nematoda sp.[3]												2
TOTAL	271	338	367	382	757	137	285	18	99	201	312	513

1 - Occurred in plankton only.
3 - Occurred in plankton and benthos.

18-b

Table 8. Yellowstone River Study - Individual Plankton Analyses - August and November 1955--Continued

	Y. 230.8 Elev. 2510 Yellowstone R. at Forsyth		Y. 182.8 Elev. 2330 Yellowstone R. At Ft. Keogh Above Miles City		Y. 181.5 T. 0.5 Elev. 2320 Tongue R. Near Mouth	Y. 136.5 Elev. 2170 Yellowstone R. At Terry	Y. 92.1 Elev. 2030 Yellowstone R. At Glendive		Y. 30.2 Elev. 1880 Yellowstone R. Above Sidney		Y. 8.9 Elev. 1870 Yellowstone R. Near Cartwright N.D. Hwy 23 Crossing	
	8/25	11/12	8/26	11/12	11/13	11/13	8/26	11/13	8/26	11/13	8/26	11/14
PHYTOPLANKTON												
GREEN ALGAE												
Chlamydomonas gr.^{3}									1			
Coccomonas^1	1						2					
Gloeocystis spp.^{3}	73		67		3		12		52		88	
Tetraspora sp.^{3}												
Sphaerocystis schroeteri^1	4											
Pediastrum duplex^3			3				1		4		2	
Pediastrum boryanum^3												
Coelastrum sphaericum^3	5		12									
Dictyosphaerium pulchellum^3									10		2	
Ankistrodesmus falcatus^3									2			
Scenedesmus bijuga^3	3			1					18		23	
Scenedesmus dimorphus^3	2		6						2		6	
Scenedesmus quadricauda^3	2		1								2	
Schroederia setigera^3	8		4						8		4	
Oocystis sp.^{1}												
Closteriopsis longissima^3	8		2						3		12	
Actinastrum Hantzschii^3			9						15		24	
Crucigenia rectangularis^1												
Closterium sp.^{3}			1								1	
Cosmarium sp.^{3}	1		1						2			
EUGLENOPHYTA												
Euglena spp.^{3}									9		3	2
Trachelomonas sp.^{1}											2	
DINOPHYCEAE												
Pleurodinium sp.^{1}								2				
DIATOMS												
Melosira granulata^3												
Melosira granulata angustissima^1	1	1	8						1		4	
Cyclotella-Stephanodiscus gr.^{3}	196	8	196	1			6		92		41	1
Stephanodiscus astraea^3	1		4			8		2		2	5	
Biddulphia laevis^3				7								
Rhizosolenia gr.^{3}	244		209	3	6	4	5		220	39	137	4
Fragilaria crotonensis^1	1		6			6					1	
Fragilaria spp.^{3}								2		3		
Diatoma vulgare^3	2	98		20		31		14		4		
Rhoicosphenia curvata^3		1		4		4						
Synedra gr.^{3}		96	3	87		168		232		88		108
Asterionella formosa^1		2	1						1	1		
Cocconeis placentula^3												
Gyrosigma gr.^{3}	8	3		1			8	2	16		8	
Navicula gr.^{3}	20	80	10	54	40	73	4	53		6	6	5
Pinnularia sp.^{3}												
Amphora veneta^3												
Gomphonema spp.^{3}						1						
Cymbella spp.^{3}				2								
Cystopleura spp.^{3}		2				6						
Rhopalodia gibba^3						2						
Nitzschia gr.^{3}	2								77		16	
Surirella spp.^{3}		4		2								
BLUE-GREEN ALGAE												
Gomphosphaeria aponina^1			4									
Dactylococcopsis sp.^{1}	5		12				4				24	
Oscillatoria gr.^{3}				4				2				
Anabaena sp.^{1}			1									
Aphanizomenon flos-aquae^1									3		16	
ZOOPLANKTON												
PROTOZOA												
Paramecium putrinum^3												
Lionotus sp.^{3}												
Strobilidium sp.^{1}												
Vorticella campanula^3											5	
ROTIFERS												
Lecane lunata^3												
Mytilina ventralis^1												
NEMATODA												
Nematoda sp.^{3}												
TOTAL	587	295	560	186	49	303	42	309	536	143	432	120

1 - Occurred in plankton only.
2 - Occurred in plankton and benthos.

18-C

Table 9. Yellowstone River Study - Relative abundance of various benthic organisms

	Yellowstone			Yellowstone				
	Above Laurel	1 mile below Laurel	Clarks Fork	3 miles below Laurel	Above Billings	Below Yegens Ditch	at Huntley	at Custer
Annelid Worms								
Leeches			Rare 11					
Tubificidae (sludge worms)	Rare 11	Abundant	Rare 11					
Snails								
Phyra sp.		NO OTHER ORGANISMS	Rare 11	Rare 11		NO BOTTOM ORGQNISMS	NO BOTTOM ORGANISMS	Rare 11
Insects								
Stone fly nymphs								
Claasenia sp.	Common 11							
Isogenus sp.	Rare 11							
Mayfly nymphs								
Heptagenia marginalis	Rare 8				Rare 8			
Habrophlebia sp.								
Choroterpes sp.			Rare 8					
Cloeon	Rare 11							
Ameletus sp.	Common 11							
Dragonfly nymphs								
Gomphus sp.								
Damselfly nymphs								
Argia sp.								
Dipterous Flies								
Chironomidae sp. (midges)	Rare 11		Rare 11					
Atherix sp. (snipe fly)	Rare 11							
Caddis Fly Larvae								
Cheumatopsyche sp.								

11 - November, 1955
8 - August, 1955

Table 9. Yellowstone River Study - Relative abundance of various benthic organisms (continued)

	Big Horn at Hardin	Little Big Horn at Hardin	Yellowstone at Myers	Yellowstone at Miles City	Yellowstone at Glendive	Yellowstone at Sidney
Annelid Worms						
Leeches						
Tubificidae (sludge worms)						
Snails						
Phyra sp.						
Insects						
Stone fly nymphs						
Claasenia sp.						
Isogenus sp.						
Mayfly nymphs						
Heptagenia marginalis						
Habrophlebia sp.					Rare 8	
Choroterpes sp.				Rare 8		Rare 8
Cloeon		Rare 11				
Ameletus sp.						
Dragonfly nymphs						
Gomphus sp.	Rare 11	Rare 11				
Damselfly nymphs						
Argia sp.			Rare 8			
Dipterous Flies						
Chironomidae sp. (midges)						
Atherix sp. (snipe fly)						
Caddis Fly Larvae						
Cheumatopsyche sp.		Rare 11				

11 - November, 1955
8 - August , 1955

Composition of the benthic fauna above Laurel was characteristic of rapids in an unpolluted stream. The absence of caddis fly larvae was unusual for cleaner sections of the Yellowstone. Rarity of bottom life in general was apparently due to DDT spraying of forests in the upper basin in July, which reportedly decimated aquatic insects in all reaches and induced heavy fish mortality by starvation. Chronic dearth of bottom fauna below Billings is apparently due to the toxic nature of oil refinery waste products and tarry bottom deposits.

Fishes

Limited observations made in November 1955 disclosed the presence of fish in Clarks Fork, in the Little Big Horn at Hardin, the Big Horn at Big Horn, and in the Yellowstone at U. S. Highway 87 Bridge outside the Yegen Ditch discharge, at Huntley, and Custer. Floating ice interfered with observations below Custer. Dead fish were found below the oil refinery and underpass drain outfalls at Laurel, in the slough receiving the Laurel treatment plant effluent, and below Yegens Ditch. A few small suckers and minnows were collected. Suckers were the common white sucker, *Catostomus commersonii sucklii*. Minnows were: *Rhinichthys atratulus melaagris*; *Rhinichthys* sp.; *Notropis* sp.; and *Hybopsis* sp.

CARBON FILTER STUDIES

Cylinders of activated carbon were installed to adsorb organic materials from raw water at the Laurel, Billings, and Forsyth water plants. Analyses of carbon extracts reported by F. N. Middleton (Attachment "A") indicated that upon two occasions (once at Billings and once at Forsyth) materials so obtained were capable of inducing an odor in the river water. The Forsyth sample was collected over the period January 19 to February 10, 1956, when sugar beet plants were not operating; and materials producing the odor (chloroform extract) were of a volatile oily nature, probably of petroleum refinery origin. The Billings sample with critical odor potential ratio was collected in November 1955, and its odor producing elements were confined to the alcohol extract. Thus it would appear that two different sources of odoriferous compounds were involved at the two localities.

Materials filtered from 100 gallons of raw sugar beet wastes were highly oxygenated and could not be readily classified into general chemical groupings used for most filter extracts. Carbon filters appear less useful for wastes of this type than for those produced by the oil industry.

Carbon filters could not be used to trace materials responsible for objectionable conditions as no such condition developed during the survey period.[1]

A complete report of the results of carbon filter studies prepared by the Robert A. Taft Sanitary Engineering Center, U. S. Public Health Service, comprises Attachment "A" following page 22.

DISUCSSION

The majority of tastes and odors occurring in surface water supplies originate either in wastes discharged to watercourses, or in algal or fungus growths. Algal increases to nuisance levels are induced by nutrients contained in waste discharges, or certain wastes kill off an innocuous algal population and produce decaying vegetation to increase the difficulty of water treatment.

In the Yellowstone River water quality impairment may result from any of the above actions. Pollutants, especially those contributed by the oil and beet sugar industries, can be directly involved when their concentrations are suddenly increased or their stabilization slowed by colder weather and flow restrictions imposed by floating ice. Combinations of certain wastes (e.g. oil and sugar beet) at some seasons may be more critical than individual pollutants. Plankton algal densities approximating nuisance levels were observed in the lower Yellowstone in August, 1952. Algal increases in response to nutrients contained in waste discharges have occurred; and possibilities exist for rapid decimation of seasonally luxuriant benthic growths.

All surveys have been conducted during periods of little or no taste and odor, and it is hardly possible to name the most responsible factor. Also, since it is difficult to differentiate among previous tastes and odors from descriptions of local personnel, the possibility exists that causative agents may have varied, with algae producing a problem at one time and industrial wastes at another. The intermittent nature of taste and odor difficulties suggests that definite combinations of circumstances are required to produce problems arising directly or indirectly from waste discharges.

ATTACHMENT "A"

YELLOWSTONE RIVER STUDY

ORGANIC CONTAMINANTS RECOVERED BY THE CARBON FILTER TECHNIQUE

ROBERT A. TAFT SANITARY ENGINEERING CENTER
4676 Columbia Parkway
Cincinnati 26, Ohio
April, 1956

SUMMARY

The objective of this survey was to determine causes of periodic taste and odor in drinking waters using the Yellowstone River as a source of supply. Since serious taste and odor problems did not develop during the survey period, it was not possible to attempt the tracing of the materials which may be responsible for the objectionable conditions previously encountered. Partial analysis was made of materials recovered from carbon filters which were operated at Laurel, Billings, and Forsyth, Montana. An additional filter was operated on the waste effluent from the Great Western Sugar Company at Billings. These data show: (1) the relative quantities of recoverable organics at the various locations (2) the odor producing potential of the organic content and (3) something of the chemical nature of the organic materials in the water.

Total chloroform and alcohol extractable materials varied in concentration from 135 p.p.b. at Laurel to 578 p.p.b. at Forsyth. The recovered materials were detectable by odor tests at concentrations ranging from 40 p.p.b. to 512 p.p.b. Based on the concentrations of materials found and the concentration of extracts detectable by odor only two instances were found when odor would have been probable in the water. Chemical breakdown of the materials revealed that neutral components were most abundant followed by water soluble materials and acidic materials. Samples from the various locations were not significantly different except for the last sample from Forsyth which was strikingly different. The last sample from Forsyth (Jan. Feb. 1956) contained a significant quantity of light hydrocarbons which are probably of petroleum refinery origin. No effects of sugar plant wastes were obvious from the carbon filter study.

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BACKGROUND

In connection with periodic tastes and odors in the city water supply of Forsyth, Montana and other cities on the Yellowstone River, the Montana Health Department through Glen Hopkins, Assistant Regional Engineer, DHEW, Region VI, requested that a study be made of contributing causes to taste and odor difficulties using the carbon filter sampling technique. Accordingly, carbon filters were shipped to Montana in September, 1955. Tastes and odors have usually developed in the fall months and have coincided with the operation of sugar refining plants in the area. However, the problem does not always occur.

Sampling Locations:

1. Laurel, Montana - finished water.

This water supply served as the control point since its location on the Yellowstone is above the principal sources of pollution which are petroleum refineries at Laurel and Billings, sugar plants at Billings and Hardin on the Big Horn River and sewage effluents.

2. Billings, Montana - finished water.

This city is about fourteen miles downstream from Laurel. Pollution from petroleum refinery operations at Laurel may reach Billings.

3. Forsyth, Montana - finished water

Forsyth is approximately 115 miles downstream from Billings. Principal effluents that may affect the water supply are the petroleum refineries, one at Laurel and two at Billings and the sugar plants - one at Billings and one at Hardin on the Big Horn River. The Big Horn flows into the Yellowstone approximately 50 miles above Forsyth.

4. For purposes of exploring the usefulness of the carbon technique on sugar plant effluents, a trial sample of effluent from the Great Western Sugar Company at Billings was passed through the filter and analyzed.

LABORATORY RESULTS

Since the carbon filter is not a standard technique, a brief explanation should help the reader in understanding the results. Several thousand gallons of the water to be tested are passed through a cylinder of active carbon at a rate of 1/4 to 1/2 gallon per minute. The carbon is dried and extracted with chloroform followed by extraction with alcohol to recover the organic materials which had been adsorbed from the water. Removal of the solvent by distillation leaves a complex residue which is then examined by chemical means. It has been found that the materials recovered by the chloroform are usually most significant as taste and odor compounds. The alcohol extraction will partially recover highly colored materials and such materials as synthetic detergents if they are present. The chloroform extractable materials are separated into broad chemical groups based on their solubility characteristics. These groups are: water solubles, amines (or bases), neutrals, weak acids (includes phenols), strong acids, and ether insolubles. Additional separation of the neutral materials by chromatographic techniques is accomplished. Taste and odor tests, infrared spectra or other determinations are made as necessary. Further interpretation of the findings will appear in appropriate sections of this report.

Table 1 shows the times of sampling, the amount of water filtered and the total amounts of organic materials recovered. The recovery of chloroform extractables at Laurel and Billings was quite low (25 to 44 p.p.b.) and compares with quantities recovered from waters where very little organic pollution exists. For example, Cincinnati tap water (source Ohio River) contains two to four times the concentration of materials found at Laurel and Billings. The organic content at Forsyth was significantly higher, reaching a concentration of 306 p.p.b. in January and February. Extraction of the carbon with alcohol, following the chloroform extraction, yielded additional organic materials ranging from 69 to 272 p.p.b.

To determine the potential odor intensity and characteristics of the recovered organic materials weighed portions of the chloroform and alcohol extracts were dissolved in odor-free water and serial dilutions of the material were presented to a panel of observers. The geometric mean of the threshold odor observations of the individuals was recorded as the threshold of the sample. Table 2 lists these results.

It is of interest to determine whether the recovered materials would be likely to produce odor in water. The relationship of the concentration of material recovered to the minimum quantity detectable by odor tests (the threshold) gives an indication of the odor potential of the materials. This relationship can be expressed by:

$$\text{Odor Potential Ratio, \%} = \frac{\text{p.p.b. of Material} \times 100}{\text{Threshold concentration in p.p.b.}}$$

If the OPR is 100 per cent or more, threshold levels are exceeded and odorous water would be likely to result. Certainly at levels of 500 per cent or over, many people would be likely to complain. Table 3 shows the OPR for the chloroform and alcohol extracts. Examination of the odor potential ratios indicates only two instances (sample 537 alcohol extract and sample 551 chloroform extract) when the recovered materials were sufficiently odorous to indicate possible odor in the water. This is in accord with observed conditions during the survey as very little odor was observed. Because of the lack of development of odorous conditions,

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detailed odor studies of the various sub-groups of materials were not made. Since phenols were measured directly on the survey, they were not tested for in the extracts.

The results of chemical separation of the chloroform extractable materials recovered appear in Table 4. These separations are based on the differences in solubility characteristics of organic chemicals and reveal, at least, gross characteristics of the materials.

Neutral compounds were most abundant of the groups recovered. Materials which may be found in this group include hydrocarbons, and such oxygenated compounds as aldehydes, ketones, ethers, and esters. The materials are usually highly odorous. Considering Laurel as the control, the only significant differences in the quantity of neutrals were on samples 537 (Billings) and 551 (Forsyth), represented by an increase. Upon chromatographing the neutral components into aliphatic, aromatic and oxygenated fractions (see Table 4) results were comparable with oxygenated substances accounting for the major portion of the materials. Aromatics in sample 546 (Forsyth) were significantly higher than those at Laurel. These data may indicate refinery materials, but this was not confirmed. Sample 551 from Forsyth during the period of January and February contained highly volatile materials of an oily nature which were not adaptable to chromatographic separation. Infrared tests indicated aromatic and olefinic materials which may be of refinery origin. The hydrocarbons recovered were much lower boiling than those we have previously encountered from petroleum refineries. It may be that cold water conditions preserved the materials.

The strong acid fractions of two samples from Forsyth were significantly higher than those from Laurel and Billings. At the same time, the neutrals were lower. Sample 551 from Forsyth showed high neutrals and low amounts of strong acids. This sample was strikingly different from all of the others. It may be surmised that biochemical oxidation was at a low level during this period since the low values obtained in the acid fractions and water solubles indicate lack of oxidized products.

Weak acids include those materials which are released from solution by carbon dioxide and include simple phenols if present. The percentage of weak acids is not, however, a guide to the amount of phenol present since many materials may fall within this group. Acidic fractions, both strong and weak are usually rather odorous.

Amines or organic bases are usually the least abundant of the groups recovered. In the samples from the Yellowstone, no significance is attached to the quantities found.

Water solubles refer to these materials which favor the water phase in a water-ether mixture. The materials are generally not significant from the taste and odor standpoint, although they constitute a substantial portion of the total organics.

A summary of the findings by cities follows:

Laurel-Lab No. 536 - Period 9-27-55 to 11-18.

The chloroform extract was a yellow brown wax of painty odor and the alcohol extract was a dark brown viscuous liquid having a caramel odor. A slight layer of oil was observed on the chloroform extract. This did not appear to be a waste component; it may have been contamination from a pump lubricant. The components of the extract appeared to be natural materials. The chloroform extractable materials and the alcohol soluble materials were about equal as odor contributors.

Billings-Lab No. 529 - Period 9-27-55 to 11-18.
537 - Period November.

Total organics were: No. 529-208 p.p.b. and No. 537-141 p.p.b. These raw extracts were similar to those obtained at Laurel. The thresholds of 430 and 40 on the chloroform extracts were significantly different. Sample 537 was unusual in that the odor contribution of the alcohol extract exceeded that of the chloroform extract. Again, as at Laurel, the natural materials and the oxidation products of these materials constituted the bulk of the sample. Refinery pollution was not evident.

Forsyth-Lab No. 528 - Period 9-27-55 to 10-4.
546 - Period 11-15-55 to 1-11-56.
551 - Period 1-19-56 to 2-10-56.

The total organics recovered showed increasing amounts (154, 253, and 578 p.p.b.). However, odor levels of the recovered extracts were not extraordinarily high although with the quantities of materials recovered on sample 551, odor would almost certainly be present. The chloroform extract of sample 551 was strikingly different from the other samples. A light yellow, somewhat volatile oil made up the bulk of the sample. Oxygenated materials were present in low amounts. The small quantity of material prevented extensive analytical tests on the materials. Infrared evidence indicates the material to be aromatic and olefinic hydrocarbons. They may be of refinery origin but certain of the usual refinery waste characteristics found in other waters we have examined are lacking.

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Sample 528 was collected prior to the operation of the sugar refineries. No. 546 was taken during the campaign and No. 551 was representative of the period after the plants closed. It is difficult to say from these data what the effect of sugar refinery waste was on the stream. One may conjecture that following the campaign, normal biological oxidation was interfered with hence the unusual sample (No. 551) at Forsyth. It is also possible that spill or unusual happening caused the difference noted.

Effluent from Great Western Sugar Plant - Billings, Montana

One hundred gallons of plant effluent was passed through a carbon filter on November 12, 1955. The dried carbon was extracted successively with ether, chloroform and alcohol. Ether and chloroform extracts were separated into chemical groups. Table 5 summarizes these results and the results of odor tests on certain of the materials. The alcohol extract accounts for the bulk of the organic content and is the principal odor contributor. This extract had a fermentive or wine-like characteristic compared with a strong acidic odor in the ether extract and a septic or stale odor in the chloroform extract. The bulk of the material recovered was composed of highly oxygenated materials and no definitive chemical characterization was practicable. While the carbon filter may have some usefulness on effluents such as those from the sugar plants, it serves best on materials not originating from biological processes.

Respectfully submitted,

F. M. Middleton

Participating in this study were:

Mr. Rice H. Burttschell performed the bulk of the analyses.

Mr. Henry Pettit performed extractions and ran infrared spectra.

Dr. A. A. Rosen assisted in interpretation of date and report writing.

All work was in the Chemistry & Physics group under Mr. M. B. Ettinger.

Table 1

RECOVERY OF ORGANIC MATERIALS FROM CARBON FILTER

Source	Laurel	Billings		Forsyth		
Lab. No.	536	529	537	528	546	551
Dates of Operation	9-27-55 to 11-18	9-27-55 to 10-5		9-27-55 to 10-4	11-15-55 to 1-11-56	1-19-56 to 2-10-56
Gallons Filtered	7,777	5,000	5,895	5,018	5,544	3,019
Quantities Recovered, Grams						
Chloroform	0.76	0.83	0.55	1.62	1.73[2]	3.49
Alcohol	3.2	3.1	2.5	1.31	3.57	
ppb[1] Chloroform	26	44	25	85	83	306
Alcohol	109	164	116	69	170	272
TOTAL	135	208	141	154	253	578

(1) p.p.b. = Parts per billion.

(2) Due to a laboratory spill, this figure may be slightly in error.

33<

Table 2

ODOR DATA

Source	Laurel	Billings		Forsyth		
Lab No.	536	529	537	528	546	551
Extract		Threshold Odor Concentration parts per billion				
Chloroform	80	439	40	395	390	107
Alcohol	256	256	40	305	256	512

Table 3

ODOR POTENTIAL RATIOS

Source	Laurel	Billings		Forsyth		
Lab No.	536	529	537	528	546	551
Odor Potential Ratio Per Cent of Extracts(1)						
Chloroform	33	10	63	28	28	286
Alcohol	41	64	290	[illegible]	67	53

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(1) $\frac{\text{Parts per Billion} \times 100}{\text{Threshold Concentration, p.p.b.}}$

Table 4

CHEMICAL GROUPS SEPARATED FROM CHLOROFORM EXTRACT

Source	Laurel	Billings		Forsyth		
Lab No.	536	529	537	528	546	551
		PERCENT OF TOTAL				
Groups						
Water Soluble	19.7	17.8	16.2	25.0	34.8	13.2
Amines	2.8	3.7	1.0	0.8	1.5	1.1
Neutrals	46.1	40.2	61.4	31.9	33.3	79.0
Weak Acids	7.5	7.7	12.3	5.6	4.5	2.1
Strong Acids	14.2	11.7	9.1	21.5	21.3	3.7
Ether insolubles	9.8	18.8	Trace	12.7	4.5	0.0
		PERCENT OF NEUTRAL GROUP				
Neutral Fractions						
Aliphatic	10.3	3.1	10.7	3.7	6.2	-
Aromatic	14.7	18.4	16.0	8.5	23.4	-
Oxy	75.0	78.5	73.3	87.8	70.2	-

Table 5

COLLECTION AND CHEMICAL DATA - EFFLUENT FROM GREAT WESTERN SUGAR COMPANY - BILLINGS, MONTANA

Source	Plant Effluent		Threshold Odor p.p.b.	Relative Odor(1) Contribution
Gallons filtered	100			
Extract recovered grams				
Ether	0.30		64	75
Chloroform	0.52		200	42
Alcohol	5.40		410	2120
ppb				
Ether	790			
Chloroform	1370			
Alcohol	14200			
Groups recovered, %	Ether	Chloroform		
Water soluble	9.8	12.0		
Amines	2.4	4.4		
Neutrals	67.5	64.9		
Weak acids	11.5	7.1		
Strong acids	8.9	11.6		
Ether insolubles	-	-		
Neutral fractions				
Aliphatic	46.4	10.6		
Aromatic	14.3	11.8		
Oxy	39.3	77.6		

(1) $\frac{\text{\% of Material x 1000}}{\text{Threshold Concentration - p.p.b.}}$

RESTRICTED INFORMATION

ATTACHMENT "B"

March 1, 1956

WASTE CONTROL EVALUATION REPORT
CARTER OIL COMPANY
BILLINGS, MONTANA

Prepared by
G. N. McDermott, Sanitary Engineer
Industrial Wastes Studies
WS and WPC Research

At the Request of
C. W. Brinck, Director
Division of Environmental Sanitation
Montana State Board of Health
Helena, Montana

Purpose

This conference and inspection was to obtain information on liquid wastes of the refinery pertinent to water pollution problems of the Yellowstone River. The information desired included elementary knowledge of the refining process and waste sources, data on the volume and character of the wastes, and details of water pollution control measures in operation.

Date of Conference

Oct. 17, 1955.

Personnel Participating

Carter Oil Company, Billings, Montana Refinery
- I. J. Staid, Manager
- R. W. Burns, Assistant Manager
- P. M. Dana, Administrative Assistant to Manager
- J. S. Bernier, Chief Chemist
- W. R. Nolt, Senior Chemist

Montana State Board of Health
- C. W. Brinck, Director, Division of Environmental Sanitation

Public Health Service
- Paul Bolton, Public Health Engineer, Water Supply and Water Pollution Control Activities, Kansas City, Missouri
- G. N. McDermott, Sanitary Engineer, Robert A. Taft Sanitary Engineering Center, Cincinnati 26, Ohio

REFINERY OPERATIONS, FACILITIES, AND PRODUCTION

Summary Description of Refinery Operations

This plant is a typical oil refinery which accomplishes the separation and purification of constituents of crude oil and conversion of some compounds to those in greater demand. Unit operations of this refinery include: primary distillation (atmospheric and vacuum), catalytic cracking, polymerization, and fluid coking. The unit processes and waste sources are discussed in greater detail in a subsequent section.

A catalytic reforming unit (hydroformer) is under construction and will be placed in operation in 1956.

The refinery at its original location was abandoned in 1949 and the refinery built new at its present location. Operation of the new plant began in June 1949.

Plant Location

The Carter Oil Company Refinery is located about three miles northeast of the city limits of Billings, Montana. The refinery proper occupies a site of about 10 acres situated between the East Billings railroad siding of the Northern Pacific and Burlington Railroads and the south bank of the Yellowstone River. This site is downstream from the city limits; the river flows to the northeast in this reach.

The refinery owns a total of about 360 acres around the refinery.

Raw Materials

Crude processed by the refinery is received primarily from Elk Basin. In addition some sweet crude is processed. These crudes are not mixed, each is run separately. The usual practice has been to run two weeks on Elk Basin crude, then three days on sweet crude. It is planned to discontinue processing sweet crude in January.

The Elk Basin crude is naphthenic type (asphaltic). The sulfur content averages about 2.5 per cent. The crude is received by pipeline and contains less than 0.1 per cent bottom sediment and water. The chloride content is low.

Other materials of interest to water pollution used by the refinery together with current average rates of use are as follows:

Salt (used in zeolite regeneration)	392 lbs/day
Soda ash (used in water treating)	171 lbs/day
Caustic (70% NaOH) (Used for sweetening)	4930 lbs/day

Polyrad 1110A (An organic amine used for corrosion control in towers)	18 lbs/day
Sulphuric acid (pH control)	0.2 gals/day
Ammonia (corrosion control)	7.5 lbs/day
Chlorine (Sweetening and water treatment)	73.3 lbs/day
Nalco #680 (Water Treatment)	9 lbs/day
Nalco # 75 (Water Treatment)	14 lbs/day
Nalco #747 (Water Treatment)	3 lbs/day
Nalco #748 (Water Treatment)	4 lbs/day

Products

Products of this refinery are:

Gasoline - 9 grades

Jet fuel

Burner fuel - 5 grades

Diesel fuel - 2 grades

Coke

Asphalts and Road Oils

Capacity

Crude intake averages about 20,000 barrels/day. Maximum rates as high as 23,500 bbls/day are reached during the peak demand season. About 3,000 of the 20,000 barrel current rate is sweet crude.

The gas oil fraction constituting the feed to the catalytic cracker amounts to 35 to 36% of the intake rate. The portion fed to the coke still varies from 0 to 12% depending on the crude being processed.

Operating Schedule

The principal operations of the refinery are continuous, 24 hours per day, 7 days per week. Some product treating operations are batch type and batches of spent chemicals are intermittently discarded to a holding tank from which they are fed uniformly to the sewers.

Individual units are taken out of production at intervals of six months, one year, or two years and cleaned. These cleaning operations are usually carried out in April and October.

Water Supply and Water Treatment

The plant water supply is obtained from the Yellowstone River. Two intakes are used. During low water an intake on the bank of the stream is used. At times of high flow river water is taken from a small earth basin which is supplied from the river by a short open earth canal. No recirculating cooling water systems with cooling towers are used. Cooling water is used once through except during extreme low temperature periods when some of the used cooling water is recirculated in order to maintain high enough temperatures to prevent formation of slush ice. Enough used water at 80° F. is returned to raise the 32° F. temperature of the incoming water to about 45° F.

The boiler feed water and potable water are softened by the hot lime-soda process, and filtered by means of an anthracite pressure filter. The boiler feed water is further softened by zeolite treatment. A Nalco compound is used for internal treatment of the boiler water.

The potable water is chlorinated using HTH and the pH adjusted by carbonation following which it is passed through a charcoal filter.

Waste Disposal

The wastes likely to be oil contaminated are passed through gravity type oil-water separators and join other wastes in a single outlet to the Yellowstone River.

Eight septic tanks are provided at various locations throughout the plant for treating wastes from toilets and shower rooms. Some of the septic tank effluents are discharged to join the waste going to the oil-water separators. Other septic tank effluents are disposed of by means of sub-surface tile leaching fields. Details of the waste treating and control practice of the plant are given in a subsequent section.

Employees

Employees normally total about 315. During peak demand this number may be increased by 25 or 30.

WASTE SOURCES, VOLUME, AND CHARACTER

A description of the refining processes sufficient to define the waste sources is given in the following sections. The cooling water used in indirect heat exchangers or coolers is not discussed for each unit.

A. Primary Distillation

Crude oil is separated into fractions, differentiated by boiling range, in continuous distillation units referred to as crude stills. The major equipment units are the furnace, atmospheric fractionator, vacuum fractionator, and auxiliary equipment such as pumps and heat exchangers. The crude is heated and introduced to the lower section of the atmospheric column. Steam is injected into the column to aid in fractionation. Desired temperatures are maintained in column sections by drawing condensate from the tower, cooling it in heat exchangers and returning it to the tower. Naphtha and gases pass overhead from the tower. Three side streams, namely, naphtha, light gas oil, and gas oil, are drawn from the column to strippers. Each side stream when drawn from the tower contains some of the lower boiling materials. To remove these traces and obtain more uniform products each of the side streams is stripped with steam in separate sections of a stripper. The overhead from each stripper re-enters the column. The steam introduced in the stripper and column plus steam created from any water contained in the crude passes overhead with the volatile hydrocarbons to a condenser. The light naphtha and water condense and flow to an accumulating drum. The water and naphtha separate by difference in specific gravity in the drum and the water is drawn off continuously to waste by means of a water level controlled valve. Ammonia is injected into the atmospheric column for corrosion control purposes. This ammonia is absorbed by the water and contained in the water drawoff. In addition to ammonia, an organic amine, trade name Polyrad 1110A, is used in the column overhead. This reduces the amount of ammonia which needs to be used. The bottoms from the atmospheric column are introduced to a vacuum column. A side stream of dry gas oil is drawn from the column and a penetration asphalt from the bottom. Steam is introduced to the column and volatile materials pass overhead to a spray type barometric condenser. Two stage steam jets are used to exhaust the noncondensibles. The barometric condenser water together with the condensibles flow to the sewers.

The gases leaving the overhead condenser are condensed and cooled. The liquefied portion is the light naphtha. The gases are compressed and conducted to the gas fractionation and recovery operations.

B. Catalytic Cracking

The heavy gas oil from the atmospheric column is fed to a fluid catalytic cracking unit. In the catalytic cracking process the gas oil is partially converted to high octane gasoline and gases through the action of heat and pressure in the presence of a silica-alumina catalyst. The products of the cracking unit are fractionated in a column. Two streams, heavy cat naphtha and recycle stock are drawn from the column to strippers. Steam is injected into the strippers as well as into the fractionating column. The light naphtha, steam and lighter hydrocarbons are conducted overhead to a condenser. The light naphtha and water flow to an accumulator where the naphtha and water separate by difference of specific gravity. The water is drawn to waste continuously by means of a water level controlled valve.

The gases leaving the overhead condenser are compressed and cooled. The liquefied portion is combined with the light cat naphtha and the uncondensed portion is conducted to the gas fractionation and recovery operations.

C. Fluid Coking

The residual oil drawn from the bottom of the vacuum column is sold as asphalt or is processed in the fluid coking unit. The fluid coking unit is the first such unit placed in operation in the world. It was placed on stream on December 25, 1954. Similar units are being built by the parent company, Esso Standard Oil Company, at its Baltimore, Maryland and Baton Rouge, Louisiana plants. A third unit has been licensed for construction at the Aurora Oil Company Refinery, Detroit, Michigan.

The process has considerable similarity to the fluid catalytic cracking process. The residual oil is sprayed into a fluidized bed of hot coke particles. Fluidization of the coke bed is obtained by injecting stripping steam at the bottom of the reactor. Volatilization of the oil feed aids in fluidization. The hydrocarbon reacts at the hot temperature to produce principally gas oil and some naphtha plus coke. The coke forms as a coating on the coke particles. To control the coke particle size steam jets are used in the reactor which by attrition maintain suitable coke particle size.

The vapors pass from the reactor through a cyclone to a fractionating column where a separation into two products is made, gas oil and naphtha vapor. The gas oil is used as part of the cat cracker feed. The overhead product is naphtha vapors and gases which are condensed and cooled. The gas goes to vapor recovery and the naphtha to the cat cracker main fractionator.

Steam injected in the reactor and adjacent transport pipes is carried from the unit as a vapor in the overhead stream. This steam condenses with the naphtha and is drawn to waste continuously, from an accumulating drum.

Coke is withdrawn from the reactor as it accumulates to a heater where it is partially burned to produce hot coke for return to the reactor. Steam is admitted to the transport lines and to the heater to maintain fluidization. The excess coke is drawn from the heater to a quench drum. Water is sprayed into the bottom of this drum, where it flashes to steam and cools the coke.

D. Naphtha Stabilization, Gas Recovery and Fractionation

Light naphtha from the catalytic cracking plant fractionator and the primary distillation unit are each fed to a stabilizer unit which removes the highly volatile hydrocarbons from the naphtha. The products are light gasolines and gases consisting generally of butane and lighter hydrocarbons.

The gases from the crude and cat cracking plants together with gases from the fluid coker fractionating column overhead are conducted to a gas recovery unit. The gas recovery units separate butane and propane fractions from the lighter gases. The lighter gases are burned in the fuel gas system.

The butane and propane fraction is fed to the polymerization unit. The poly unit is a hydrocarbon rebuilding process employing a phosphoric acid catalyst which forms high quality gasoline from the feed gases.

The feed to the polymerization plant is washed with diethanolamine (DEA) to remove sulfides, then washed with caustic to remove mercaptans and finally water washed to remove caustic traces. The diethanolamine is regenerated and reused.

Wastes from these operations are the spent caustic from polymerization plant feed wash, wash water from polymerization plant feed wash, and small amounts of water drawn from accumulating tanks. The latter are considered negligible.

E. Sweetening Operations

Sweetening refers to the removal of sulfides and mercaptans from refinery products. Several methods are employed at this refinery for different products.

The overhead and top side stream from the crude distillation unit fractionating column is combined and treated for sulfide removal by the bauxite treatment process. The bauxite decomposes sulfides and disulfides as well as mercaptans. The sulfur compounds are then fractionated from the gasoline in a fractionating column referred to as the after fractionator. The bauxite may be regenerated by burning the carbon off.

Light virgin naphtha from the after fractionator is further sweetened by the Girbotol process which uses diethanolamine for removing sulfides. The DEA is regenerated. After Girbotol treatment the mercaptans are converted to disulfides by passing the naphtha through a bed of solid copper chloride beads. The copper beads are regenerated continuously by aeration.

The light cat naphtha is combined with polymerization plant gasoline and given caustic and HOCl treatment to remove mercaptans, acid oils and phenols. The hypochlorite is used in a caustic solution. After the hypochlorite is spent the solution is used for caustic wash. The spent caustic is discharged to the neutralizer.

The heavy cat naphtha is treated separately by caustic washing followed by air inhibitor sweetening. The air inhibitor sweetening consist of the addition of a reagent, Universal Oil Products No. 5, in small amounts and aerating. The spent caustic is discharged to the neutralizer. The UOP No. 5 remains with the heavy naphtha which is stored slightly sour and sweetens in storage.

Burner fuel is sweetened by treatment with bauxite, following which it is caustic washed and hypochlorite treated.

Gas oil (for diesel fuel blending) is passed through a sand filter for coagulation of the water. Very small amounts of water are occasionally drawn to the sewer from the filter.

The wastes from these operations consist of the spent caustic solution. These spent caustics in addition to containing high concentrations of sulfur bearing compounds absorb phenols and cresols. All spent caustic solutions of the plant are pumped to a tank where they are neutralized by treatment with H_2S gas. This treatment is carried out as a batch operation. The acid oils tend to separate from the neutralized caustics, such oils contain most of the phenols and cresols. The acid oils are skimmed from the surface of the neutralizing tank and burned. The skimmed neutralized caustic solution which now contains principally sodium sulfide is fed to the sewer through a small orifice in order to prevent a slug discharge.

F. Miscellaneous Wastes

1. Pump Gland Cooling Water and Gland Leaks

Pump glands are cooled by a stream of water which flows through passages surrounding the gland. Frequently some leakage of the hydrocarbon being pumped past the packing gland will occur. Such leakage will be contained in the cooling water which flows to the sewers.

2. Steam Turbine Condensing Water

Steam is drawn through steam turbines and a vacuum produced by means of indirect condensers which require large volumes of water. Such condensing water at this plant is used once through and sewered.

3. Tank Car Cleaning Wastes and Loading Area Spills

The loading of products and unloading of crude oils from tank cars and trucks results frequently in significant spills and leaks to the platform area. In this same area tank cars are received and drained of any residual material. Some tank cars are cleaned at this location although most of the cars used here are cleaned at Laurel, Montana.

4. Water Treating Wastes

The softening of the water supply produces softening plant sludge. Regenerating brine solutions are produced from zeolite softeners. Solids concentration in the boilers is controlled by a continuous blowdown to waste.

45-a

G. Summary of Waste Sources

The volume of cooling water used once-through in various heat exchangers and condensers of the processing units and turbines constitutes probably over 95% of the volume of waste discharged from the plant. Most of the cooling water is used in indirect heat exchangers and therefore its quality is not affected. No recirculation of cooling water through cooling towers is practiced in the plant.

Significant process wastes, the sources of which were discussed in preceding paragraphs, are listed below, together with estimates of phenol contents and volumes. These estimates are based on information obtained at other refineries and upon information supplied by company representatives. The figures should be considered as indicating the order of magnitude and not accurate to any appreciable degree.

TABLE 1

SIGNIFICANT PROCESS WASTES AND ESTIMATED VOLUME AND PHENOL CONTENT

Waste Source	Estimated Volume, Gallons Per Day	Phenol Content Per Day Pounds
Cooling water from indirect coolers and pump glands	20,000,000	0
Barometric condenser water from vacuum distillation unit	100,000	1.5
Water drawoff from primary distillation unit fractionating column	8,000	1
Water drawoff from catalytic cracking unit fractionating column distillate drum	9,000	13
Water drawoff from coker naphtha accumulating drum	30,000	12
Water wash of polymerization plant feed	5,000	Negligible
Neutralized spent caustics	3,000	40
	20,000,000	67

47

WATER POLLUTION CONTROL PROGRAM

Segregation of Some Uncontaminated Cooling Water

Cooling waters used in two of three shell and tube condensers for power turbines in the plant are discharged to a separate sewer, by-passing the general plant sewers which flow to the oil-water separators. The quality of this water is not significantly changed through such use except for temperature increase. The by-pass sewer joins the separator effluents and flows together with all other plant wastes in a single outfall channel to the Yellowstone River. By-passing this water around the separators serves to reduce the volume of flow through the separators and thereby increases their efficiency.

Gravity Type Oil-Water Separators

The remainder of the refinery wastes are discharged to one of two separate sewer systems, each of which leads to its own oil-water separator. These two sewer systems are referred to as the clean water system and dirty water system. The clean water system receives about two-thirds of the flow, consisting mostly of cooling water used in heat exchangers. The clean water system separator is constructed according to the latest A.P.I. design, utilizing the vertical slot type baffles in the inlet chamber. The separator consists of two parallel sections each approximately 14 x 69 feet.

The separator serving the dirty water system receives leaks, spills and storm drainage from the paved areas in the refinery, pump gland cooling water, laboratory wastes, sampling tap wastes, neutralized spent caustic, water drawoffs, polymerization plant feed wash water, and other miscellaneous wastes of the refinery. The dirty water separator is also of the latest A.P.I. design. It consists of two parallel chambers approximately 100 x 40 feet.

It was noted in both of the separators that the vertical slot baffling arrangement at the inlets was not evenly distributing the flow across the width of the compartment. It is believed that the baffles had been spaced across each compartment as if the sewer carrying the waste to the inlet entered at the center of the compartment. However, since there were two parallel compartments the sewer entered the inlet compartment opposite the common wall between the two compartments.

At the time that the dirty water system separator was observed it appeared that an emulsion existed. Spherical globules of black oil were aggregated on the surface and the underlying water appeared milky. This appearance is typical of emulsions forming in the so-called white water from washing acid treated oils.

Slop oil recovered from the oil-water separator is treated to break emulsions and the oil returned to process. Sludge from the oil-water separators is discharged to a shallow open earth pit.

Neutralization and Controlled Discharge of Spent Caustic

The neutralization of spent caustics with H_2S has been described in the process section. This operation is conducted in batches, the aeration of each batch requiring about six hours. After a period of quiescence the acid oils are skimmed off. A valve at the bottom of the neutralizing tank is opened and the neutralized solution discharged through a small orifice to the dirty water sewer system.

It is believed that the discharge of the neutralized solution to the oil-water separator may prevent optimum efficiency of the separator through the tendency to form or stabilize emulsions. It would appear advisable to bypass the separator with this spent chemical solution. Since the solution has undergone a quiescent settling and skimming in the neutralizing tank it seems unnecessary to discharge it through the oil-water separator. The practice in neutralizing chemical solutions observed at another plant provided sufficient capacity in the neutralizing tank for several days caustic production. The daily discharge from the tank amounted to a few feet only of drawdown. This practice enables optimum efficiency in separation of oil because a long period for oil separation is provided. Very uniform discharge is also easily obtained because the change of head on the orifice is small.

Segregation of Water Treating Waste

The water softening sludge, zeolite regenerating waste and boiler blowdown are discharged to the sewer which bypasses the oil-water separator. This practice prevents possible interference with oil-water separation and reduces the sludge in the separators. The type of materials used in boiler water treatment apparently are not those with significant toxicity.

Septic Tank Treatment of Sanitary Sewage

All the sanitary sewage is treated in septic tanks distributed throughout the plant. Some of these septic tanks discharge to the dirty water sewer above the separator. Effluents of other septic tanks are disposed of through subsurface leaching fields.

Planned Additional Waste Control Measures

An additional oil-water separator to be located at the loading rack area is planned for installation in 1956. Additional paving is also planned for the loading rack area. This separator will enable the separation of oil from the leaks, spills, and car cleaning wastes from this area before they are diluted with other plant wastes. This should result in an increased oil recovery.

A major additional unit is being constructed at the refinery which will influence the wastes. This unit is a hydroforming unit of the platinum type which will be used to increase the octane rating of the heavy naphthas from the crude distillation unit. The hydroformer will include hydrofine desulfurization which will replace the present bauxite unit. The product of the unit will be given caustic wash. An overall decrease in spent caustic solutions will result from this addition.

It is planned to discontinue the use of the pits for disposing of sludge from the oil-water separators. Plans are to treat the sludge for recovery of oil and burn the residual sludge in an existing rotary incinerator.

/Sgd/ G. N. McDermott
Sanitary Engineer
Industrial Wastes Studies
WS and WPC Research
Robert A. Taft Sanitary
Engineering Center

APPROVED:

/Sgd/ Glen J. Hopkins
Sanitary Engineer Director

YELLOWSTONE RIVER STUDY
AS
RELATED TO CARTER OIL REFINERY
BILLINGS, MONTANA

A comprehensive study of waste discharges to the Yellowstone River from above Laurel to below Sidney, and to the Big Horn River from above Hardin to its confluence with the Yellowstone, was made during the period November 7 to 13, 1955.

Waste discharged to the Yellowstone River by the Carter Refinery consist of the effluents of the clean and dirty water separators and the wastes bypassing these separators. The waste outlet, an open channel from separators to the river, is located so near the raw water intake that both raw and waste water were sampled in the river study to ascertain if refinery wastes gained entrance to the raw water supply.

Except for the coking unit and polyreactor, the refinery was in complete operation during the period of study. These units were closed for "turnaround" operations. Some phosphoric acid catalyst is lost to the sewers during cleaning of the polyreactor.

Twelve grab samples, collected at 2-hour intervals from approximately 7:00 a.m. on November 8, to 5:00 a.m. on November 9, from the raw water intake and from the waste effluent, were composited according to flow. Rates of flow were taken from the raw water meter, the rate of raw water pumpage being considered equivalent to waste flow. Mr. E. L. Sanders, Analyst for the Carter Oil Company, assisted in collecting samples. Results are shown in Table 2.

Analyses substantiate that wastes from the refinery enter the raw water supply. Pollution discharged from the refinery during the 24 hours was calculated as the difference between raw water and waste analyses. During the 24-hour period of study 25.3 million gallons of water were used by the refinery. Based on temperatures of 5° C. in the river, 10.3° C. in the raw water and 19.9° C. in the waste, recirculation on the day of composite amounted to 9.1 MGD. Subtracting 135 pounds of phenol as recirculated from the 377 pounds gives a discharge to the river of 242 pounds. Using a 3-day average river content of phenols at Billings H_2O intake and adding the total quantity of these compounds discharged in wastes between the point of river sampling and the raw water intake gives a river content of 3.54 ppb. Using phenol content as a basis 8.93 MGD are recirculated. The sum of the river water content plus that recirculated deducted from the total quantity discharged from the plant is equal to 249 pounds to the river. It is apparent there is close correlation among all methods of calculation.

The pH of raw water at 7:00 a.m. was 8.4 and the waste 8.5.

TABLE 2

YELLOWSTONE RIVER STUDY
NOVEMBER 1955
CARTER OIL COMPANY
BILLINGS, MONTANA

November 8-9

	Raw Water	Waste	Waste Actual
Flow MGD	25.3	25.3	25.3
pH			
Average	8.1	7.1	7.1
Maximum	8.6	8.7	8.7
Minimum	5.9	4.7	4.7
Oxygen Consumed ppm	19.6	140.1	120.5
B.O.D. 5-Day 20° C.			
ppm	3.4	31.7	28.3
Pounds	718	6,700	5,982
Suspended Solids			
ppm	14	50	36.0
Pounds	2,955	10,550	7,595
Phenol Compounds			
ppb	630	1,781	1,151
Pounds	133	377	244
Chromium			
ppm	$<.001$	$<.001$	0
Pounds	$<.21$	$<.21$	0
Temperature			
Average	10.3	19.9	19.9
Maximum	14.0	21.0	21.0
Minimum	8.5	18.5	18.5

Production per day
bbls. crude - average 20,000
November 8 and 9 - 18,087

Oxygen consumed was 120.5 parts per million (ppm), indicative of a waste relatively low in chemical oxygen demand. This analysis is a measure of the oxygen required to stabilize the wastes through chemical reaction. The ratio of oxygen consumed to B.O.D. indicates a waste highly active chemically. The 5-day 20° biochemical oxygen demand of the waste was recorded as 28.3 ppm, giving a total of 5,982 pounds of B.O.D. for the 24-hour period of study. This is equivalent organically to the domestic sewage from 35,892 people.

A suspended solids content of 36.0 parts per million was recorded. Phenol content of 630 ppb (parts per billion) and 1,781 ppb was found in the raw water and waste, respectively. Total phenols discharged to the river, as calculated by difference between raw water and waste analyses, is 244 pounds. This is more than five times the total of phenols found to be discharged from all other sources in the area.

Traces of chromium were found in the same quantities in the wastes and in the raw water. Copper and lead determinations were not completed on this particular waste.

While determinations were not made, oil was clearly visible in the waste stream. Oils, whether separable or in the emulsion form, should be eliminated from plant effluent. Quantities are quite variable in refinery wastes and require constant monitoring and control.

A comparison of the data in Table 1 of this report, based on information obtained during the October 17, 1955, evaluation of this refinery, and studies at other refineries, emphasizes need for additional waste prevention or control. While the measured quantity of flow of 25.3 MGD corresponds closely to reported average usage of 20 MGD from the Company's records, the 244 pounds of phenols in the wastes are more than three and one-half times the expected losses.

While dissolved oxygen content approached saturation during the week of study, and was depressed only at isolated points, other effects of the heavy organic load on the Yellowstone River were readily visible.

Discussion

Phenols and related compounds have been under close scrutiny in the Yellowstone River due to taste and odor problems at downstream public water supplies. Presence of phenolic compounds in the river below Billings has been previously demonstrated by work of the Montana State Board of Health. Cyclic development of tastes and odors during the fall months is highly indicative of phenolic compounds in combination with other organic wastes. Low river temperatures materially reduce the rate of biological destruction of phenols, making the problem more acute in winter months. Synergetic action of organic wastes discharged in large amounts from other sources, particularly in the fall of the year may also be a factor.

Oxygen consumed was 120.5 parts per million (ppm), indicative of a waste relatively low in chemical oxygen demand. This analysis is a measure of the oxygen required to stabilize the wastes through chemical reaction. The ratio of oxygen consumed to B.O.D. indicates a waste highly active chemically. The 5-day 20° biochemical oxygen demand of the waste was recorded as 28.3 ppm, giving a total of 5,982 pounds of B.O.D. for the 24-hour period of study. This is equivalent organically to the domestic sewage from 35,892 people.

A suspended solids content of 36.0 parts per million was recorded. Phenol content of 630 ppb (parts per billion) and 1,781 ppb was found in the raw water and waste, respectively. Total phenols discharged to the river, as calculated by difference between raw water and waste analyses, is 244 pounds. This is more than five times the total of phenols found to be discharged from all other sources in the area.

Traces of chromium were found in the same quantities in the wastes and in the raw water. Copper and lead determinations were not completed on this particular waste.

While determinations were not made, oil was clearly visible in the waste stream. Oils, whether separable or in the emulsion form, should be eliminated from plant effluent. Quantities are quite variable in refinery wastes and require constant monitoring and control.

A comparison of the data in Table 1 of this report, based on information obtained during the October 17, 1955, evaluation of this refinery, and studies at other refineries, emphasizes need for additional waste prevention or control. While the measured quantity of flow of 25.3 MGD corresponds closely to reported average usage of 20 MGD from the Company's records, the 244 pounds of phenols in the wastes are more than three and one-half times the expected losses.

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Other factors which may intensify the objectionable effects of phenols are: variations in production of the numerous industries; spills, accidental or otherwise; toxic materials as heavy metals, in sufficient concentration to produce inhibiting effects; and raising and lowering of the river level, thereby flushing out observed impoundments or sludge deposits. Oils in waste effluents may also be a factor.

Recommendations

It is recommended that:

1. The paving of the loading rack area be completed.

2. A thorough study be made of each individual source of waste within the plant to delineate and evaluate actual sources of phenols, oils, caustic, and acid.

3. Phenols and related compounds be virtually eliminated from plant wastes. This can be accomplished by reclamation, reduction in losses, and biological treatment for residual wastes. Reduction in the volume of water used may be an important step in the waste control program.

4. All oils be virtually eliminated from plant wastes. Existing and planned separators will substantially reduce separable oils, but have very little effect on emulsions. Provision for emulsion breaking should be made as necessary to virtually eliminate oil in the wastes discharged to the stream.

5. Acidic or caustic wastes be neutralized and drawn off at a controlled rate that will preclude adverse effect on treatment units or the receiving stream.

6. Toxic wastes be withheld or discharged at a controlled release that will reduce the concentration below allowable limits in the river.

7. An effective monitoring and control procedure be established over all plant wastes so that none can be released without adequate treatment.

8. Increased attention be given to pollution control during the "turn-around" period.

9. A comprehensive plan of pollution control, including a time schedule of installation and construction, be prepared and submitted at the earliest possible date to the Montana State Board of Health for review. As much of the program as possible should be completed prior to the fall of 1956.

/Sgd/ Glen J. Hopkins
Sanitary Engineer Director

RESTRICTED INFORMATION

54<

ATTACHMENT "C"

February 28, 1956

WASTE CONTROL EVALUATION REPORT
CONTINENTAL OIL COMPANY
BILLINGS, MONTANA

Prepared by

G. N. Mc Dermott, Sanitary Engineer
Industrial Wastes Studies
WS and WPC Research

At the Request of
Montana State Board of Health
Helena, Montana

Purpose

This conference and inspection was to obtain information on liquid wastes of the refinery pertinent to water pollution problems of the Yellowstone River. The information desired included elementary knowledge of the refining process and waste sources, data on the volume and character of the wastes, and details of water pollution control measures in operation.

Date of Conference

October 18,1955.

Personnel Participating

CONTINENTAL OIL COMPANY, BILLINGS,MONTANA REFINERY
- H. G. Owen, Assistant Superintendent
- L. E. Adee, Technologist
- G. H. Unzelman, Resident Chemist

MONTANA STATE BOARD OF HEALTH
- C. W. Brinck, Director, Division of Environmental Sanitation

PUBLIC HEALTH SERVICE
- Paul Bolton, Public Health Engineer, Water Supply and Water Pollution Control Activities, Kansas City, Missouri
- G. N. McDermott, Sanitary Engineer, Robert A. Taft Sanitary Engineering Center, Cincinnati 26, Ohio

REFINERY OPERATIONS, FACILITIES, AND PRODUCTION

Summary Description of Refining Operations

This oil refinery accomplishes the separation and purification of constituents of crude oil and converts some compounds to those in greater demand. Unit operations of this refinery include: Primary distillation and fractionation, catalytic cracking, and polymerization. The unit processes and waste sources are discussed in greater detail in a subsequent section.

A catalytic reforming unit is under construction and will be placed in operation in the spring of 1956.

Plant Location

The Continental Oil Company Refinery is located at the east boundary of Billings just outside the city limits. The company owns 115 acres of land in the vicinity of the refinery.

Raw Materials

Crude processed by the refinery is received from a number of fields and varies considerably in character. The various sources of crudes and their sulfur content are tabulated below. The major quantities are received from the first four listed in the tabulation. The Cat Creek and Sumatra crudes are received at the rate of approximately 100 barrels per day each. All the crudes are combined for refining except Ash Creek which is stored and processed separately. Cat Creek crude is not passed through the desulfurization process.

The crudes contain only a trace of salt, therefore do not require desalting. Water in the crude is low. There is no problem with emulsions or sediment accumulating in crude storage tanks except for Sumatra crude which tends to dewax in storage. Once in six years operation the waxy emulsion had to be broken with Tret-o-lite and removed from the tank.

Crude	Sulfur Content %	Remarks
Silvertip	2.3 to 2.5	
Frannie-Elk Basin	2.3 to 2.5	Naphthenic
Williston Basin	0 to 0.8	
Ash Creek Crude		Sweet Paraffin Base
Cat Creek Crude		Light Sweet Crude
Sumatra Crude		

Other materials used by the refinery which are of interest to water pollution are as follows:

Material	Use	Units per day
Ammonia (Anhydrous)	Corrosion Control in Fractionating Columns	30 lbs/day
Caustic (70% NaOH)	Sweetening	730 lbs/day in 1933 660 lbs/day in 1954 390 lbs/day in 1955
Litharge	Doctor Treatment	3 lbs/day
Copper Sulphate ($CuSO_4 \cdot 5H_2O$)	Perco Treatment	39 lbs/day
Soda Ash	Water Treating	100 lbs/day
Remox (Sodium Sulfite)	"	30 lbs/day
Lime (CaOH)	"	150 lbs/day
Salt	"	40 lbs/day
HCl (6%)	pH control in copper sweetening	3 lbs/day
Orocol 129P	Water treating	32 lbs/day
Chlorine	"	40 lbs/day
A Gel (Lignin base)	"	33 lbs/day
H_2SO_4	"	220 lbs/day

Products

Gasoline - 3 grades
Jet Fuel
Power Fuel (Tractor Fuel)
No. 1 Distillate (Heating Oil)
Diesel Fuel
Fuel Oil No. 6
Liquefied Petroleum Gases

Capacity

Crude intake averages about 10,500 barrels per day on a normal on-stream day.

Operating Schedule

The principal operations of the refinery are continuous, 24 hours per day, 7 days per week.

The entire plant is shut down for several days once per year for clean-up and maintenance work.

Water Supply and Water Treatment

The water supply is obtained from the city of Billings. The Billings Water Treatment Plant is located nearby and supplies the plant with finished water.

All water used for cooling is recirculated through cooling towers which minimizes use of water. The circulating cooling water is treated with Orocol, sulfuric acid, and chlorine. The Orocol is a chromate and phosphate compound obtained from the Betz Company. It is fed continuously to the water in amounts sufficient to maintain a 50 to 70 ppm concentration. Sulfuric acid is added to maintain a pH near 7. Chlorine is used for slime and algae control and is added in shots of 2 hours duration each 12 hours.

Boiler water makeup is softened by the hot lime-soda process. The boiler water is treated internally using a polyphosphate corrosion inhibitor, A-Gel (lignin) and sodium sulfite.

Waste Disposal

Wastes are discharged to Yegen Ditch. Yegen Ditch is an open drainage channel which discharges into the Yellowstone River at a point immediately upstream from U. S. Highway 87 Bridge. Details of waste treating and control practice are given in a subsequent section.

Sanitary sewage is conveyed by a separate sewer system to the city sewers.

Employees

Employees normally total between 140 and 145.

WASTE SOURCES, VOLUME AND CHARACTER

A description of the refining processes with emphasis on liquid waste sources is given in the following sections covering each unit of the refinery. Cooling water used in heat exchangers and condensers is from the recirculated cooling water system.

Primary Distillation

Crude oil is separated into fractions, differentianted by boiling ranges, in continuous distillation units referred to as crude stills. The major equipment units are the furnace, fractionating columns, and auxiliary equipment such as pumps and heat exchangers. The unit at this refinery is rather unique in that the fractionation is carried out in two stages with a desulfurization unit between. In the primary distillation unit the crude is heated and introduced to the lower section of the primary fractionator. Desired temperatures are maintained in the sections of the tower by drawing condensate from the tower, cooling it in heat exchangers and returning it to the tower. Three streams are drawn from the primary fractionator: an overhead stream in vapor phase consisting of diesel fuels and lighter fractions, a side stream in the gas oil range, and reduced crude from the bottom.

The overhead stream is conducted to a desulfurization unit where it is contacted with cracking catalyst at a lower temperature than used in the catalytic cracker. The sulfur-hydrocarbon compounds of these low boiling fractions are decomposed into hydrogen sulfide which is separated in later fractionating steps, thereby producing practically sulfur-free stocks. The catalytic desulfurization produces also a mild cracking of the stock.

The hydrocarbons from the desulfurizer are fractionated in the secondary fractionator into five cuts. The lightest stream, to 250°, is conducted overhead to condensers.

Each side stream when drawn from the tower contains some of the lower boiling materials passing through it to sections above. To remove these traces and obtain more uniform products each of the side streams is stripped with steam in separate sections of a stripper. The overhead stream from each stripper containing steam and volatilized hydrocarbons is fed back to the fractionating column. Steam is also injected into the fractionating column to aid in separation. The steam introduced in the stripper and column plus steam produced from the water content of the crude is contained in the overhead stream of the column. The water and higher boiling hydrocarbon fraction condense in the condenser and flow to an accumulating drum. The water separates from the naphtha in the accumulator and is drawn to waste continuously by means of a water-level control operated valve. This waste is referred to as water draw-off from the crude distillation fractionating column overhead stream. Ammonia is introduced into the crude distillation unit to control corrosion. The ammonia is injected continuously and amounts to about 30 pounds per day. The ammonia is ultimately contained principally in the water-drawoff from the overhead stream. This stream amounts to about 10 gallons per minute.

The uncondensed gases flow to the gas recovery operations.

The products of the secondary fractionator go to sweetening operations or to market.

The gas oil stream is fed to the catalytic cracker.

The reduced crude is fed to the deasphalting unit.

Catalytic Cracking

The gas oil from the primary fractionator is fed to the UOP fluid catalytic cracking unit. In the catalytic cracking process the gas oil is partially converted to high octane gasoline and gases by means of heat and pressure in the presence of a silica-alumina catalyst. The products of the cracking unit are fractionated in a column. Two streams are drawn from the column to strippers. Steam is injected into the strippers and into the fractionating column. One side stream is used as absorber oil in the catalytic gas absorbers. Steam injected in the strippers, fractionating column, and risers together with light napthas and more volatile hydrocarbons are conducted overhead to a condenser. The light naphtha and water flow to an accumulator where the naphtha and water separate by difference in specific gravity. The water is drawn to waste continuously by means of a water level controlled valve. This water amounts to about 10 gpm. It contains H_2S, some elemental sulfur, and phenols.

The gases leaving the condenser are compressed and cooled. The liquefied portion is combined with the light cat naphtha and the uncondensed portion is conducted to absorbers of the gas recovery and fractionation operations.

Deasphalting

The bottom stream from the primary fractionating column of the crude still is fed to a deasphalting unit. The deasphalting unit uses liquefied propane to dissolve the feed stock. The mixture is then heated which precipitates the asphalt. The asphalt is removed in settlers and blended with cycle stock from the catalytic cracker to produce #6 fuel oil.

The supernatant phase is a gas-oil which is combined with gas-oil from the crude distillation unit and fed to the cat cracker.

The propane is recovered from both the gas oil and asphalt phases. In this operation steam is used to strip residual propane from the asphalt and oil. The overhead vapors are cooled by indirect contact spray condenser which discharges at the rate of about 20 gpm to the sewers. This water is drawn from the recirculating water cooling system and is the bleed-off to control the build-up of solids in the cooling water.

Naphtha Stabilization, Gas Recovery Fractionation, and Polymerization

In naphtha stabilization units the butane and lighter gases are separated from light naphtha of the primary distillation unit. The uncondensed gases and uncondensed gases from the catalytic cracker are fed to an absorber or deethanizer where ethane and lighter gases are removed. The butane and propane gases are then contacted with diethanolamine (DEA) to remove sulfides. The absorbed sulfides are subsequently removed from the DEA and vented to the fuel gas line. The DEA solution is recirculated. In the near future the sulfide gas will be sold to the Montana Sulfur & Chemical Company for sulfur manufacture.

Following the DEA treatment the gases are scrubbed with caustic solution which is recirculated countercurrent to the gas flow in a packed tower.

The caustic wash is followed by a water wash in another tower. The water wash is for the purpose of removing caustic traces and nitrogen bases consisting principally of various amines and substituted ammonia compounds. These compounds poison the catalyst of the polymerization plant if permitted to remain in the gases.

The purified gases are fed to the polymerization plant which employs a phosphate catalyst. The olefins present polymerize to a gasoline. The products are fractionated into polymer gasoline, butane, propane and lighter gases.

Wastes of the unit consist of spent caustic from the caustic wash and waste from the water wash.

Sweetening Operations

Sweetening refers to the removal of sulfides and mercaptans from refinery products. Several methods are employed at this refinery for different products. This is in addition to the bauxite treatment of all light fractions previously described.

The catalytically cracked naphtha in the gasoline range are sweetened using a 3-stage caustic wash in the presence of a small amount of air and a UOP #3 gum inhibitor. The caustic is contained in three raschig ring packed towers and the gasoline passed through in series. In addition to sulfides and mercaptans the caustic removes the acid oils (phenol, cresol, thiophenols, etc.). Phenol itself is not objectionable in the gasoline in that it has some gum inhibiting properties but thiophenols catalyze gum formation in gasoline and must be removed. The phenols are removed incidental to the removal of thiophenols. As the acid oil content builds up in the caustic it is shifted from tower to tower so as to obtain counter-current extraction. The caustic is withdrawn when the acid oil content reaches 50%. The spent caustic and acid oils are shipped to California. The mixture is not neutralized or stripped; the entire mixture is shipped.

No. 1 distillate is caustic washed in a single stage drum system. The caustic removes the hydrogen sulfide and lower mercaptans. This faction does not normally contain a significant amount of phenols and cresols. Spent caustic from distillate sweetening is reused for catalytic naphtha treating as subsequently discussed.

Straight run gasoline is treated by the standard Perco treatment using a $CuCl_2$ solution. The copper chloride solution oxidizes the mercaptans to disulfides and is itself reduced to the cuprous state. The liquid solution is then oxidized with air in a separate vessel and returned to the contact tank. Copper sulfate and sodium chloride are used as makeup chemicals. The copper chloride treatment is followed by a sodium sulfide after wash which is the final step in the copper sweetening. It is designed to remove any traces of copper that may remain in the gasoline stream leaving the copper solution. Spent caustic from the polymerization plant feed caustic wash and spent caustic from caustic washing of distillate, which are principally caustic solutions of sodium sulfide, are used in this after wash. The sulfides react to precipitate any copper carryover.

About 10 barrels of spent caustic are transferred at three week intervals from the polymerization plant feed wash to the primary distillation unit gasoline wash. About 30 barrels of spent caustic are transferred at six month intervals from the distillate sweetening to the primary distillation unit gasoline wash. The combined spent caustic solution is discarded from the Perco treating unit after wash when the sodium chloride content has built up higher than desired. This spent solution is discharged with the plant effluent as subsequently described. About 200 barrels per year are discharged. This solution contains sodium sulfide, sodium chloride, sodium carbonate, and some copper which will be precipitated in the form of copper sulfide.

Some distillate is occasionally doctor treated which converts the odorous mercaptans to disulfides by reaction with alkaline sodium plumbite solution (Na_2PbO_2) containing a little elemental sulfur. The doctor solution is repeatedly regenerated by heat and aeration and reused. About 500 barrels per day of distillate is treated when this unit is used. It is anticipated that doctor sweetening will be discontinued when the new reforming unit is in operation in 1956. There has been no loss or discard of spent solutions from this operation during the last 18 months. There have been losses in the past due to leaks but these have been corrected. Makeup litharge is added to the solution at intervals of about 3 months.

Reforming

A catalytic reforming unit of Continental Oil Company design is under construction and will be completed in 1956. The unit will process crude distillation unit products down through heavy diesel fuels and will increase the octane rating utilizing a platinum catalyst. The process includes a cobalt molybdenum type desulfurizing unit. This unit will eliminate the need for doctor sweetening of distillate and reduce the use ofcaustic in sweetening of straight run products. No liquid wastes are anticipated from this unit.

Miscellaneous Wastes

1. Loading Rack Drainage

Some wastes consisting of leaks, spills, and car drainage originate in the loading rack area. No car cleaning operations are carried out at the plant and pump out equipment is installed for returning the contents of any car to the refinery process. Some spills and leaks are to the ground. The sewered wastes are conducted to the oil-water separators.

2. Recirculated Cooling Water System Drawoff

Solids tend to build up in the recirculated cooling water because of evaporation. A bleed-off from the recirculated cooling water is made in order to limit the concentration of solids. The bleed-off is regulated so as to maintain a maximum of 4.5 to 5 times the concentration of total solids. This bleed-off is accomplished by using the recirculated cooling water system as a water source for the polymerization plant feed wash and the deasphalting unit direct condenser water. This water would contain the chemicals used for water treatment.

3. Water Treating Wastes

Wastes from water treating consist of water softening sludge and boiler blow-down. Water softening sludge is discharged manually during a period of about 1/2 hour each day. Boiler blowdown is both manually and continuous. Blowdown is between 6% and 10% of the makeup and amounts to between 15,000 to 24,000 gallons per day. These wastes are discharged to a separate sewer which by-passes the oil-water separator.

4. Fire Wall Drainage and Storm Runoff

Storage tanks of crude oil, and intermediate and refined products are encircled by earth embankments, the purpose of which is to catch the tank contents in event of a tank rupture. These walls are referred to as fire walls; the outlets are kept closed, consequently natural rainfall would tend to accumulate in them. In addition any water accumulating in the bottom of a storage tank may be drained in the fire wall area. At this plant the rainfall is low and the ground highly permeable, consequently no waste results from this source. Surface runoff from the paved areas in the refinery and from some roof drains enter the sewers leading to the oil-water separator. Other storm drains by-pass the separator. The separator effluent joins this storm sewer and the boiler blowdown by-pass to form the refinery effluent. The storm sewer carries some steam trap drainage.

5. Pump Gland Cooling Water

Pump glands are cooled by a flow of water which passes through passages about the packing glands. This water is likely to be contaminated with any leaks of hydrocarbon streams past the packing glands. At this refinery the use of water is minimized by using mechanical seals where appropriate and by providing for the return of some of this cooling water to the recirculated cooling water system.

6. Laboratory and Sampling Wastes

Laboratory wastes may contain significant quantities of hydrocarbons, particularly if pilot-plant work is being carried out. In collecting samples for process control around the plant frequently appreciable hydrocarbons are sewered in drawing long sampling lines to obtain fresh samples.

7. Wastes at Time of Annual Plant Clean-up

Once per year all units are shut down and cleaned. Units and lines are steamed out to minimize catalyst loss and are then washed. Much of the material washed from the units is iron sulfide. The wash waters are dark from the sulfide particles. The volume of wastes may be somewhat more than normal at the time but plant officials believe the waste load will be reduced with the exception of iron sulfide.

Caustic solutions are stored during this time. There are no dumps of accumulated wastes or spent caustics at the time of the clena-up.

Summary of Waste Sources

A tabulation of major waste sources, together with information on volume and principal objectionable constituents of each, are summarized in Table 1.

TABLE 1

SUMMARY OF WASTE SOURCES, VOLUME, AND CHARACTERISTICS

	Source of Waste	Volume Gallons Per Day	Principal Objectionable Constituents
1.	Water Drawoff from Primary Distillation Unit Naphtha	14,000	Phenols
2.	Water Drawoff from Catalytic Cracking Unit Distillate	14,000	Phenols
3.	Polymerization Plant Feed Wash	17,000	
4.	Propane Deasphalting Plant Condenser Water	29,000	
5.	Spent Caustic (Sodium Sulfide) Solution from Sweetening	23	NaS Mercaptans Caustic
6.	Pump Gland Cooling Water		Oil
7.	Loading Rack Area Drainage		Oil
8.	Laboratory, Sampling, and Miscellaneous Wastes		Oil
9.	Boiler Blowdown and Softening Sludge	20,000	Water Treating Chemicals Solids

The refinery effluent rate of discharge ranges from 90 to 120 gallons per minute with an average of about 100 gpm.

WATER POLLUTION CONTROL PROGRAM

Measures in Operation

1. Shipping of Spent Caustic Solution from Catalytic Gasoline Sweetening

The spent caustics from caustic treating of gasoline fractions produced in the catalytic cracking unit is shipped to California where it is processed for recovery of certain constituents. This caustic contains the major portion of phenols and cresols produced by the refinery and is therefore a waste control measure of major importance. Shipment of this waste has been carried out since June of 1955.

2. Controlled Discharge of Remaining Spent Caustics

The remaining spent caustics are collected in a tank and discharged at a slow even rate, thereby controlling the concentrations reached in the receiving water. This solution is not discharged continuously and there may be long periods when none is discharged. The spent caustic enters the sewer which by-passes the oil-water separator.

3. Treatment in Gravity Oil-water Separator

The oil sewer from the process area and tank farm is treated in a two-section gravity oil-water separator which was constructed when the refinery was built in 1948. The separator is divided longitudinally into two compartments, approximately 19' 6" wide by 78' long between the entrance flow distributor and the effluent weir. Water depth is 4' 10-1/2". The flow distributor of each compartment consists of nineteen 8" pipes equally spaced across the entrance.

Flow through the separator is normally less than 80 gpm. The separator more than meets the recommended A.P.I. minimum requirements as to retention time, overflow rate, and maximum velocity.

Slop oil is skimmed from surface of the separator and steam heated to break emulsions. The water is returned to the separator inflow and the oil is returned to process.

Each of the separator compartments can be operated separately. Compartments are taken out of service and cleaned of sludge twice a year. The sludge is slurried and pumped to a pit. The sludge is burned in the pit and the residue buried.

Spent caustic, boiler blowdown, and softening sludge by-pass the separator. They join the separator effluent following the straw filters.

4. Straw Filters for Removing Oil Traces

Two series of straw filters consisting of three mats each are installed in the channel below the separator. The straw filters are changed usually once per week and the used material burned.

5. Cooling Water Recirculation

The practice of recirculating cooling water to a maximum extent at this refinery keeps the volume of the wastes to a minimum and therefore aids in controlling oil losses and lessens the load to the oil-water separator.

Experimental Research on Additional Measures

The residual phenol load of the refinery has its source principally in the water-drawoff from the catalytic cracked distillate. The company has been experimenting with methods of removing this phenol.

One promising method reported was the extraction of the water draw-off with light cycle gas oil. A material reduction in phenols was accomplished by such extraction. The phenols would be returned to the process with the gas oil. There might be some destruction of them in the unit or ulitmately they would be found in the naphtha and consequently in the caustic used for sweetening.

/Sgd/ G. N. McDermott
Sanitary Engineer
Industrial Wastes Studies
WS and WPC Research
Robert A. Taft Sanitary
Engineering Center

APPROVED:

/Sgd/ Glen J. Hopkins
Sanitary Engineer Director

YELLOWSTONE RIVER STUDY
AS
RELATED TO CONTINENTAL OIL REFINERY
BILLINGS, MONTANA

A comprehensive study of the Yellowstone River from Laurel to below Sidney, Montana, and the Big Horn River from Hardin to its mouth was completed during the period November 7 to 13, 1955. The purpose was to evaluate the effects of waste discharges on taste and odor problems encountered in water supplies serving Forsyth, Miles City and Glendive, Montana, and Williston, North Dakota. The problems have developed periodically over a number of years, and on occasions have been extremely severe.

Samples composited from 12 grab samples collected at 2-hour intervals from each major source of wastes were analyzed. Table 2 is a tabulation of the results from analyses of waste from the Continental Oil Refinery collected from 8:00 a.m., November 8, to 5:00 a.m., November 9. Three days of river samples were also analyzed and studied to determine effects of wastes discharged.

The total quantity of waste discharged by this industry was 140,000 gallons for the 24-hour period. The pH varied from a maximum of 8.9 to a minimum of 8.2, and averaged 8.5. Oxygen consumed was 909.9 parts per million, evidencing a waste high in chemical oxygen demand. Strength of the waste in terms of 5-day 20° C. biochemical oxygen demand was 627 ppm, or a total discharge of 732 pounds. Suspended solids were 222 ppm, or 259 pounds; this is quite low compared to the biochemical oxygen demand. Phenolic compounds in the amount of 13.66 pounds were discharged in a concentration of 11,700 parts per billion. Minor amounts of copper, chromium and lead were also present in the wastes. Temperatures ranged from a high of 26 to a low of 24 for an average of 24.7° C.

Dissolved oxygen levels in the stream waters approached saturation during the week of study, and were depressed only at isolated points. However, other effects of the heavy organic load on the Yellowstone were readily visible.

Discussion

Phenols and related compounds have been under close scrutiny in the Yellowstone River due to taste and odor problems at downstream public water supplies. Presence of phenolic compounds in the river below Billings has been previously demonstrated by work of the Montana State Board of Health. Periodic development of tastes and odors during the fall months is highly indicative of phenolic compounds in combination with other organic wastes. Low river temperatures materially reduce the rate of biological

TABLE 2

YELLOWSTONE RIVER STUDY
NOVEMBER 1955
CONTINENTAL OIL REFINERY
BILLINGS, MONTANA

	November 8-9
Flow MGD	.14
pH	
Maximum	8.9
Minimum	8.2
Average	8.5
Oxygen Consumed ppm	909.9
B.O.D. 5-Day 20° C.	
ppm	627
Pounds	732
Suspended Solids	
ppm	222
Pounds	259
Phenolic Compounds	
ppb	11,700
Pounds	13.66
Copper	
ppm	.04
Pounds	.047
Total Chromium	
ppm	.07
Pounds	.082
Lead	
ppm	.02
Pounds	.024
Temperature °C.	
Maximum	26
Minimum	24
Average	24.7
Production	
Bbls crude processed	10,418

destruction of phenols, making the problem more acute in winter months. Synergetic action of organic wastes discharged in large amounts from other sources, particularly in the fall of the year, may also be a factor.

Other factors which may intensify the objectionable effects of phenols are: variations in production of the several industries; spills, accidental or otherwise; toxic materials as heavy metals, in sufficient concentration to produce inhibiting effects; and raising and lowering of the river level, thereby flushing out observed impoundments or sludge deposits. Oil in waste effluents may also be a factor.

Recommendations

It is recommended that the commendable program of control and elimniation of pollution be continued to provide that:

1. Phenols and related compounds, and free and emulsified oils, be virtually eliminated from plant wastes.

2. Toxic metallic wastes be withheld or discharged at a controlled release that will reduce the concentration below allowable limits in the river.

3. Increased attention be given to pollution control during the "turnaround"period.

4. Appropriate treatment be provided for the wastes bypassing the separator, possible in combination with the separator effluent.

5. A program for additional improvements in pollution control, including provision to preclude all spills from plant discharges, be formulated and submitted to the Montana State Board of Health for review and approval. The program should include a time schedule for installation of proposed improvements.

/Sgd/ Glen J. Hopkins
Sanitary Engineer Director

RESTRICTED INFORMATION

November 5, 1955

ATTACHMENT "D"

WASTE CONTROL EVALUATION REPORT
GREAT WESTERN SUGAR COMPANY
BILLINGS, MONTANA

Prepared by
G. N. McDermott, Sanitary Engineer
Industrial Wastes Studies
WS and WPC Research

At the Request of
C. W. Brinck, Director
Division of Environmental Sanitation
Montana State Board of Health
Helena, Montana

1. Purpose

This conference and inspection was for the purpose of obtaining information on liquid wastes of the beet sugar plant relative to the water pollution problems of the Yellowstone River. The sources of wastes in the process, volume and character of total and component wastes and the pollution control measures in operation were investigated.

2. Date of Conference

October 19, 1955.

3. Personnel Participating

GREAT WESTERN SUGAR COMPANY
- Lloyd Jensen, District Superintendent
- R. L. Kimmons, Manager
- I. L. Johnson, Assistant Manager
- Steve Foerst, Superintendent

MONTANA STATE BOARD OF HEALTH
- C. W. Brinck, Director, Division of Environmental Sanitation

PUBLIC HEALTH SERVICE
- Paul Bolton, Public Health Engineer, Water Supply and Water Pollution Control Activities, Kansas City, Missouri
- G. N. McDermott, Sanitary Engineer, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio

PLANT OPERATIONS, FACILITIES AND PRODUCTION

4. Summary Description of Operations

This plant employs the standard processes of beet sugar refining, including beet fluming, battery type diffusers, lime purification and hot and cold Steffen process. Approximately two-thirds of the pulp is pressed and dried and the remainder is stored in wet silos. The factory was built in 1906. Changes made since that date include addition of pulp driers and some changes in the purification system.

5. Plant location

The plant is located in the southeast corner of the city of Billings near the Yellowstone River. The company owns 152 acres of land in the vicinity of the plant.

6. Raw Materials

Sugar beets
Limestone
Coal
Coke
Sulfur
Nalco water treating compound

The factory slices about 3650 tons of sugar beets daily. In addition, about 60 tons of straight-house molasses from other plants of the company is processed in the Steffen operation, making a total of about 175 tons per day of molasses processed in the Steffen operation.

7. Products

Sugar
Wet pulp
Dried pulp

8. Operating Schedule

The operation is seasonal, generally commencing between October 5 and 16, and lasting about 100 days. The 1955 operations are expected to end about December 27, 1955. During the campaign the factory operates continuously, 24 hours per day, 7 days per week. However, some wastes are produced on an intermittent schedule, namely, pulp screen water from intermittent dumping of diffuser batteries and filter cloth rinse water.

9. Employees

During the campaign approximately 300 people are required to operate the factory. During the remainder of the year about 70 employees work at the factory.

10. Water Supply and Water Treatment

Water for process purposes is obtained from the Yellowstone River from which it is pumped to the plant at the rate of about 8,000 gallons per minute. City water is used for washing the saccharate cake in the Steffen process and for the sanitary supply. River water used in the barometric condenser is treated with Nalco water treating compounds which are adjusted phosphates. The standard practice of reusing evaporator condensate for boiler feed water and battery water supply is employed.

11. Waste Disposal

The liquid wastes of the plant, with the exception of lime cake slurry, are discharged through two adjacent outfall sewers to Yegen Ditch. Yegen Ditch is an open drainage channel which discharges into the Yellowstone River at a point just upstream from the U. S. Highway 87 Bridge. The lime cake slurry is discharged to ponding areas on land adjacent to the factory. It is possible for these ponds to overflow to other drainage canals leading to Yegen Ditch. Details of waste treatment are given in a subsequent section.

The sanitary sewage from toilets and wash rooms of the plant is discharged without treatment to the sewers carrying the process waste.

PROCESS DESCRIPTION AND WASTE SOURCES

The beets are received by rail or truck at the plant and are passed over a special screen, the purpose of which is to remove clay and sand from the beets. The beets are then stored in open piles.

12. Beet Fluming and Washing

Beets are stored in piles above a system of flumes. As the beets are needed the covering on the flume is removed and the beets allowed to drop into the flume water. Water flowing in the flumes conveys the beets to the beet factory building. In fluming the beets dirt is washed from them and is transported along with the flume water. Readily settleable mud is removed from the flume water in a special section of the flume and is hauled to nearby land. A mechanical trash catcher operates in the flume to remove beet leaves, weeds, straw, and trash. This material is trucked away for cattle feed. The beets are discharged from the flume to a beet wheel which elevates them from the flume water to a washer. The flume water flows into the sewer. The washer is a vat type rectangular chamber equipped with agitators. Fresh water is admitted and waste water released continuously. It joins the flume water in the sewer. The washed beets are lifted from the washer to a roller table. A series of small rolls on the table tend to break up and remove remaining tap roots from the beet itself. These roots and spray rinse water used on the roller table are pumped to a screen which recovers the roots for cattle feed. The water flows to waste. The beets are sliced and conveyed to the diffuser.

13. Diffusers

This plant is equipped with two cell-type diffusion batteries. Each battery consists of a series of fourteen cylindrical steel tanks each of which holds several tons of sliced beets. Sugar is extracted by passing hot water through the sliced beets in the tank. A counterflow principle is employed using an intricate piping system so as to permit the liquor to pass progressively from one cell to the next in series. The cells are filled with sliced beets in series and dumped in similar sequence. Fresh battery supply water enters the cell containing sliced beets which have been longest in the system and from which therefore most of the sugar has been extracted. The water then passes progressively through cells which have been under diffusion decreasingly shorter periods of time, and leaves the battery after passing through the cell which has been most recently filled with sliced beets. The liquid drawn from the diffusion battery is known as "raw juice" and contains 10% to 13% sugar plus non sugars.

Cells containing the sliced beets which have completed the diffusion process are dumped through quick-opening gates in the bottom of the cells and the cells rinsed by hand-directed hoses. The water and sliced beets (now called pulp) are collected in a flume underneath the battery.

14. Pulp Screening and Pressing

The pulp is disposed of by two means. About two-thirds of the pulp is pumped to the pulp drying operation, where it is first drained on screens and then further dewatered in screw type presses before being dried in a rotary kiln type drier. The pulp screen water and pulp press water from the drying house are drained to the sewer. The remaining one-third of the pulp is pumped as a water suspension to a screen located above an open earth basin referred to as the pulp silo. The screen above the silo is a horizontal screen over which the pulp is moved by flight type drag. From appearances this screen produced a much drier pulp than the A-frame type. The pulp screen water flows to the sewers.

15. Pulp Storage

The pulp silo is provided with an underdrain system which is covered with wooden planks. Water contained in the screened pulp drains from the pulp through spaces left between the plank flooring to the sewers. The pulp is hauled from the silo to feed yards as needed.

16. Juice Purification

The raw juice from the diffusers is given chemical treatment and filtration to remove the suspended matter and non sugars. Calcium saccharate, which is produced in a later stage in the process, is added to the raw juice and carbon dioxide is bubbled through until a certain alkalinity is reached. The precipitate which is formed is separated from the juice by settling. The sludge from the settling unit is filtered on drum type vacuum filters and sugar traces are rinsed from the filter cake. The rinsed filter cake is scraped from the filter, slurried and pumped to a pond. The juice is given a second treatment with carbon dioxide and the precipitate removed by plate and frame filters. When the filters are disassembled the cake is slurried and pumped to the drum type filter previously described. The filter cloths are washed in an agitated water bath similar to a commercial laundry unit. The sugar-rich first washings are returned to the raw juice. Further wash waters are sewered.

17. Evaporation

The partially purified juice is next treated with sulfur dioxide gas to a certain alkalinity. The juice is concentrated in multiple effect evaporators and refiltered on plate and frame filters. When these filters become dirt clogged the cloths are removed and washed as described previously for other filter cloths.

Water is further evaporated from the sugar in vacuum pans until crystallization of the sugar has produced crystals of the desiredsize. The sugar crystals are separated from the liquid by centrifuging. The residual syrup is further evaporated and centrifuged a second time and finally a third time. Sugar from the second and third crystallization, being impure, is remelted and returned to the process for recovery in first crystallization. The resulting molasses following third crystallization and centrifuging is either subjected to the Steffen process for additional sugar recovery or is added to the dried pulp.

Vacuum on the evaporators is produced by means of spray type condensers. The condensing water is discharged through barometric legs. Condensates from the bodies of the multiple effect evaporators are used for washing sugar on the centrifuges, for washing filter cake on the filters, and as part of the battery supply.

18. Steffen Process

In the Steffen process, molasses from the third centrifuging is diluted with water and lime is added under carefully controlled conditions. A calcium saccharate precipitate is formed and filtered from the dilute molasses. The filtrate is then heated to approximately 85° C. in order to precipitate additional saccharate which is separated by a second filtration. The filtrate is known as Steffen waste and, at the present time, is sewered.

The saccharate cake is diluted and used for raw juice purification immediately prior to carbonation. Non-sugars are associated with the saccharate cake. These non-sugars are returned to the raw juice with the saccharate cake and become increasingly concentrated in the molasses as the process continues. In order to eliminate the non-sugars it is necessary to remove a portion of the third centrifuge molasses from the system. The molasses is used for cattle feed. The effect of accumulating inseparable non-sugars is alleviated by using third centrifuge molasses from a factory not employing the Steffen process. After non-sugars have built up in the molasses it is discarded and replaced with molasses from the other factories (referred to as foreign molasses). The Billings plant processes molasses from one of the plants of the Great Western Sugar Company located in Wyoming.

ESTIMATED WASTE VOLUMES AND CHARACTERISTICS

Studies of the volume and characteristics of liquid wastes have been made at other beet sugar plants. The data obtained in these studies, together with information on the process used and production rate of this plant, enable the estimation of waste volumes and characteristics. Table 1 lists the estimated volume, BOD, and suspended solids of the component wastes from the Billings plant. These estimates are based on 3650 tons per day rate of beet processing and 175 tons per day of molasses processing in the Steffen operation. It was also assumed that two-thirds of the pulp was dried and one-third stored in wet silos. The values should be considered as only rough approximations.

TABLE 1

ESTIMATED VOLUME AND CHARACTER OF INDUSTRIAL WASTES

GREAT WESTERN SUGAR COMPANY, BILLINGS, MONTANA

Waste	Flow gal/day	B.O.D. 5-Day 20° C. ppm	B.O.D. 5-Day 20° C. lbs/day	Suspended Solids ppm	Suspended Solids lbs/day
Flume Water *	9,500,000	210	16,400	1,000	79,200
Pulp Screen Water	880,000	980	7,200	530	3,900
Pulp Press Water	440,000	1,710	6,300	420	1,540
Pulp Silo Drainage	260,000	7,000	15,000	270	580
Lime Cake Slurry	330,000	8,600	23,700	120,000	331,000
Steffen Waste	462,000	10,500	40,400	350	1,350
Total Discharged** to Yegen Ditch	11,500,000	890	85,000	900	86,600

* Includes barometric condenser water, and beet wash water.

** Total of all components except lime cake slurry which is ponded.

WATER POLLUTION CONTROL PROGRAM

19. Waste Control Measures in Operation

Beginning with the campaign of about the year 1942, the lime cake slurry has been diverted to a pond located adjacent to the refinery. This settling pond site contains about forty acres. It was estimated that at the present time about two feet of sediment has been deposited on the area. The pond is not constructed for complete impoundment of the slurry, but following several weeks operation an overflow has occurred in the past. A new area is being used during the current campaign. Company officials do not believe this new area will overflow this year. The pond is formed by low earth dike placed around a relatively level area. When the pond overflows the effluent enters an open ditch which joins the Yegen Drain approximately one-quarter mile upstream from the point of entrance of the plant sewers.

Grate ashes from the boiler house are transported as a slurry to an impounding basin adjacent to the factory. The overflow from the ash pond returns to the boiler house for fluming more ashes. Fresh river water is used for makeup water for ash fluming. The provision of facilities for removing mud from the flume water may also be considered a waste control measure.

20. Future Plans for Waste Control

No specific plans for further water pollution control are definitely scheduled by the company. However, Great Western Sugar Company has developed a process for utilizing all Steffen waste from their Colorado and Nebraska plants. They are currently investigating the possibilities of evaporating the Steffen waste and shipping it to their glutenate plant at Johnstown, Colorado. The company also has plans for ultimately modernizing all their plants, which will include the installation of continuous diffusers. Elimination of the Steffen waste and pulp screen and pulp press water under this program would appreciably reduce the waste load of the factory.

/Sgd/ G. N. McDermott
Sanitary Engineer
Industrial Wastes Studies
WS and WPC Research
Robert A. Taft Sanitary
Engineering Center

APPROVED:
December 19, 1955

/Sgd/ Glen J. Hopkins
Sanitary Engineer Director

March 26, 1956

YELLOWSTONE RIVER STUDY AS RELATED TO GREAT WESTERN SUGAR REFINERY

BILLINGS, MONTANA

A comprehensive study of the Yellowstone River from Laurel to below Sidney, Montana, and the Big Horn River from Hardin to its mouth was completed during the period November 7 to 13, 1955. The purpose was to evaluate the effects of waste discharges on taste and odor problems encountered in water supplies serving Forsyth, Miles City and Glendive, Montana, and Williston, North Dakota. The problems have developed periodically over a number of years, and on occasions have been extremely severe.

In order to determine the total quantity and characteristics of wastes discharged by this industry, 24-hour composite samples, consisting of 12 grab samples at 2-hour intervals, were collected from Yegen Ditch immediately below the discharge of the sugar refinery. Data resulting from this study are tabulated in Table 2. The quantity of waste, 19.5 million gallons, was obtained by rate measurements on Yegen Ditch, above and below the outlet. The difference in flow less the quantity of flow in the 42-inch storm sewer above the plant was used as the net plant discharge.

Laboratory findings were typical of sugar refineries. The pH varied from 8.2 to 10.6, and averaged 9.4. Oxygen consumed was 1,096 parts per million. Biochemical oxygen demand was 535 parts per million, and suspended solids 3,700 ppm. The 87,100 pounds of B.O.D. and 602,000 pounds of suspended solids thus indicated are equal to 24 and 165 pounds, respectively, per ton of beets sliced. While some reduction occurs in Yegen Ditch due to exertion of immediate oxygen demand and settling out of solids, most of this high organic load reaches the Yellowstone.

Phenolic compounds were found in the wastes, as were trace amounts of heavy metals. Concentrations indicate these come from the raw water or are introduced from other sources, as leaching from the soil, rather than the refinery. Temperature of the wastes ranged from 24 to 18° C. for an average of 21.8.

Study of the river, at times selected to be indicative of effects of the composited waste discharges, confirmed heavy pollution. While dissolved oxygen at the points of sample collection was near saturation except at isolated points, adverse effects of organic pollution were readily apparent.

Discussion

Measured biochemical oxygen demand discharged compares favorably with experience data at comparable plants as shown by a comparison of Tables 1 and 2. The suspended solids contribution is greatly in excess of evaluated estimates.

TABLE 2

YELLOWSTONE RIVER STUDY
NOVEMBER 1955
GREAT WESTERN SUGAR COMPANY
BILLINGS, MONTANA

	November 8-9
Flow MGD	19.5
pH	
Maximum	10.6
Minimum	8.2
Average	9.4
Oxygen Consumed ppm.	1,095.8
B.O.D.	
ppm	535
Pounds	87,100
Suspended Solids	
ppm	3,700
Pounds	602,000
Phenol	
ppb	15.6
Pounds	2.54
Copper	
ppm	.01
Pounds	1.63
Chromium	Trace
Lead	
ppm	.01
Pounds	1.63
Temperature °C.	
Maximum	24.0
Minimum	18.0
Average	21.8
Production	
Tons of Beets Sliced	3,640.0

The history of tastes and odors in water supplies taken from lower Yellowstone establishes their occurrence in fall or winter months. They coincide with lower water temperatures and the impact of heavy loads of organic material from sugar refineries. The 1955 study of the Yellowstone River and tributaries, including all major sources of pollution, establishes that industrial wastes are discharged in sufficient quantities to provoke severe taste and odor problems.

Colder water temperatures markedly reduce the rate of oxidation of organic materials at the time when the heaviest load is discharged to the streams. Effects thus extend over a much greater distance. Synergistic effects of sugar refining wastes and other pollutants known to be present appear to be the basic cause of taste and odor problems.

Settling of solids on the stream bed also aggravates the situation. Subsequent digestion and movement of these sludge beds by fluctuating river levels introduces relatively short periods of heavy pollution that increases taste and odor potential. The major source of organic solids in the river system is the wastes produced by beet sugar refineries.

Recommendations

It is recommended that:

1. Improvements be made in waste control as necessary to virtually eliminate floating and settling solids and to reduce 5-day 20° C. B.O.D. to not more than 8 pounds per ton of beets sliced.
2. Effective monitoring and control procedures be established over all plant wastes so none can be discharged without adequate control.
3. A comprehensive plan of pollution control, including a time schedule of installation and construction, be prepared and submitted at the earliest possible date to the Montana State Board of Health for review. As much of the program as possible should be completed prior to the fall of 1956.

/Sgd/ Glen J. Hopkins
Sanitary Engineer Director

RESTRICTED INFORMATION

ATTACHMENT "E" December 27, 1955

WASTE CONTROL EVALUATION REPORT
HOLLY SUGAR COMPANY
HARDIN, MONTANA

Prepared by
G. N. McDermott, Sanitary Engineer
Industrial Wastes Studies
WS and WPC Research

At the Request of
C. W. Brinck, Director
Division of Environmental Sanitation
Montana State Board of Health
Helena, Montana

Purpose

This conference and inspection was to obtain information on liquid wastes of the beet sugar plant pertinent to water pollution problems of the Yellowstone River. The information desired included elementary knowledge of the plant processes and waste sources, data on the volume and character of the wastes, and details of water pollution control measures in operation.

Date of Conference

October 20, 1955.

Personnel Participating

HOLLY SUGAR CORPORATION
- E. O. Preston, Superintendent
- T. A. Weir, Master Mechanic
- Gene Kelly, Chief Chemist

MONTANA STATE BOARD OF HEALTH
- C. W. Brinck, Director, Division of Environmental Sanitation

PUBLIC HEALTH SERVICE
- Paul Bolton, Public Health Engineer, Water Supply and Water Pollution Control Activities, Kansas City, Missouri
- G. N. McDermott, Sanitary Engineer, Robert A. Taft Sanitary Engineering Center, Cincinnati 26, Ohio

PLANT OPERATIONS, FACILITIES, AND PRODUCTION

Summary Description of Operations

This plant employs the standard processes of beet sugar refining employed in straight house operation. The Steffen process is not used. The processes include beet fluming, battery type diffusers, and lime purification. The pulp is drained on a screen and stored in the wet state in an open silo. The Hardin Plant was first placed in operation in 1937. An ion exchange unit for purifying the extracted juice was installed in 1949. This unit by removing impurities increased the recovery of sugar and reduced the production of molasses. The process has been deemed uneconomic to operate under existing market conditions for molasses. The equipment has been disassembled and is for sale.

Plant Location

The plant buildings are located approximately 2-1/2 miles northeast of Hardin and 1/2 mile from the west bank of the Big Horn River. The factory is situated on a 40 acre tract owned by the company which in addition owns a 160 acre tract to the south of the plant.

Raw Materials

Sugar Beets
Limestone
Coal
Coke
Sulfur

Diatomaceous earth filter aid
Nalco water treating compounds

The plant during a normal day's operation slices about 1850 tons of beets per day. On peak days 2000 tons or more may be processed.

The rates of processing beets at this plant are as follows:

1850 tons per day - normal operation.

2000 tons per day - peak days.

1818 tons per day - Average 1954 campaign.

1881 tons per day - Average 1953 campaign.

Products

Sugar
Wet Pulp
Molasses

Operating Schedule

The operation is seasonal, generally commencing between October 5 and 16, and lasting about 100 days. The 1955 operations are expected to end about December 25, 1955.

Employees

During the campaign approximately 180 people are required to operate the refinery. During the remainder of the year about 30 employees work at the factory.

Water Supply and Water Treatment

Water for process purposes is obtained from the Big Horn River. Two pumps are installed for this purpose, one rated at 4000 gpm and one 600 gpm. The intake is located below the confluence of the Big and Little Horn Rivers and below the sewage outfalls of Hardin. The intake is upstream from the beet sugar plant outfall sewer.

Drinking water is hauled from the city water supply.

Waste Disposal

The liquid wastes of the plant with the exception of lime cake slurry are discharged into the Big Horn River at a point about a mile downstream from Hardin. A 24" outfall sewer carries the wastes about 1/2 mile from the plant to the river. The lime cake slurry is discharged to farm land as discussed in more detail in a subsequent section. Sanitary wastes are conducted to the process waste sewers and flow to the river without treatment.

PROCESS DESCRIPTION AND WASTE SOURCES

The process and equipment employed at this plant which are of interest to water pollution are described in the following paragraphs.

Beet Fluming and Washing

The beets when received are passed over screens for removal of soil and debris before they enter a channel referred to as a flume. Water flowing in the flume transports the beets into the plant and acts as a wash to remove much of the loose soil from the beets. Large balls or chunks of mut settle out in a sunken section along the floor of the flume and are removed over the side of the channel by flight type conveyors.

The beets are elevated by a wheel to another section of flume in which additional water is added and a trash collector operates to remove beet leaves, weeds, and debris from the water and beets. The water and beets are discharged to second beet wheel. Flume water passes to a coarse

84<

screen called a grizzly and thence to the sewer. Usable pieces of beets are recovered from the screenings and the trash and leaves hauled away for use as cattle feed. The beets are elevated by the wheel to a beet washer. Fresh water is added to the washer continuously and overflows to waste with the flume water.

The combined flume and wash water constitutes the first significant waste of the process. Condenser water used to produce a vacuum on the evaporators and vacuum pans is used for flume and wash water supply. Occasionally pulp screen water is used for fluming in addition to the condenser water.

Diffusers

The washed beets are sliced into long narrow ribbons and discharged to diffusers. This plant is equipped with a cell-type diffusion battery. The battery consists of a series of cylindrical steel tanks or cells each of which holds several tons of sliced beets. Sugar is extracted by passing hot water through sliced beets in the tanks. A counterflow principle is employed using an intricate piping system so as to permit the diffusion liquor to pass progressively from one cell to the next in series. The cells are filled with sliced beets in rotation and dumped in similar sequence. Fresh battery supply water enters the cell containing sliced beets which have been longest in the system and from which therefore most of the sugar has been extracted. The water then passes progressively through cells which have been under diffusion decreasingly shorter periods of time and leaves the battery after passing through the cell which has been most recently filled with sliced beets. The liquid drawn from the diffusion battery is known as "raw juice", and contains 10 to 13 percent sugar plus other non-sugars.

Cells containing the sliced beets which have completed the diffusion process are dumped through quick-opening gate in the bottom of the cell and the cell rinsed by hand directed hoses. The water and sliced beets (now called pulp) are collected in a flume underneath the battery.

Pulp Screening and Storage

The pulp is pumped as a water suspension to an A-frame type screen which is located above a basin constructed of earth dikes and referred to as the pulp silo. The pulp suspension is delivered at the apex of the screen. Pulp slides down the screen and drops to the silo. The water separated on the screen is collected and returned to the sewer or to the beet flume. This waste is termed pulp screen water.

The pulp silo is provided with an underdrain system which is covered with planks spaced approximately 1/4" apart. Water drains from the pulp in the silo and as decomposition of the pulp takes place water is formed which adds to the drainage. This water draining from the silo to the sewer is referred to as pulp silo drainage.

Juice Purification

The raw juice from the diffusers is given chemical treatment and filtration to remove the suspended matter and non-sugars. Powdered lime which is produced in a kiln at the plant is added to the raw juice and carbon dioxide is bubbled through until a certain alkalinity is reached. The precipitate which forms is separated from the juice by sedimentation. The sludge from the settling unit is filtered on drum type vacuum filters and sugar traces rinsed from the filter cake. The rinsed filter cake is scraped from the filters, slurried, and disposed of as described in a subsequent section. The juice is given a second treatment with carbon dioxide and the precipitate removed by means of plate and frame filters. The filter cake removed is slurried and pumped to the vacuum filters where it mixes with the other lime mud. Carbon and filter aid are used in the filtration and are discharged with the lime slurry. The combined waste is referred to as lime cake slurry.

Evaporation

The filtered juice is treated with sulfur dioxide gas to the desired pH level. The juice is then concentrated in multiple effect evaporators and filtered again on plate and frame filters. The filter cake from these filters is disposed of as described previously for other filter cake.

Water is further evaporated from the sugar in vacuum pans until crystallization of the sugar takes place and crystals have grown to the desired size. The sugar crystals are separated from the liquid by centrifuging. The residual syrup is further evaporated and centrifuged a second time, and finally a third time. Sugar from the second and third crystallization being impure is remelted and returned to the process for recovery in first crystallization. The resulting molasses following third crystallization and centrifuging is marketed.

Vacuum on the evaporators and vacuum pans is produced by spray type condensers discharging through barometric legs. The condenser water is used for fluming beets and for a portion of the diffuser battery supply. This water is slightly contaminated by entrainment and volatilization of materials from the juices. Condensates from the bodies of the multiple effect evaporators are used for boiler feed water, for washing sugar on centrifuges, for washing filter cake on the filters, and as a part of the diffuser battery supply.

Condensate from the body of the second effect of the multiple effect evaporators contains considerable ammonia from breakdown of nitrogenous materials in the first effect. This contamination makes it inadvisable to use the water for boiler feed water or for diffusion. It is used for washing lime mud from the filter presses and for various clean-up purposes.

86

Miscellaneous Wastes

Miscellaneous wastes of the plant include filter cloth washings, floor and equipment washing, waste from the sample house, slurried ashes from the boiler house, and boiler blowdown. Wastes from the sample house constitute a considerable volume. Samples of each load of beets are weighed and washed in small high pressure spray type washers to determine the tare on the loads delivered to the refinery.

ESTIMATED WASTE VOLUME AND CHARACTERISTICS

Studies of the volume and characteristics of liquid wastes have been made at other beet sugar plants. The data obtained in these studies, together with information on the process used, and production rate of this plant, enable the estimation of waste volumes and characteristics. Table 1 lists the estimated volume, BOD, and suspended solids of the component wastes from the Hardin Plant. The values should be considered as only rough approximation. However, they should be useful in planning waste control measures.

TABLE 1

ESTIMATED VOLUME, BOD, AND SUSPENDED SOLIDS IN WASTES OF HARDIN BEET SUGAR PLANT HOLLY SUGAR COMPANY, HARDIN, MONTANA*

Waste	Flow gal/day	BOD		Suspended Solids	
		ppm	lbs/day	ppm	lbs/day
Flume Water	4,800,000	210	8,300	2,000	80,000
Pulp Screen Water	440,000	980	3,600	530	1,900
Pulp Silo Drainage	390,000	7,000	23,000	270	880
Lime Cake Slurry	170,000	8,600	12,000	120,000	170,000
Barometric Condenser Water	3,700,000**	40	1,200	-	-

*Based on 1850 tons/day of beets processed.

**Dual use for flume water.

WATER POLLUTION CONTROL PROGRAM

Waste Control Measures in Operation

1. Broad Field Disposal of Lime Cake Slurry

The lime cake slurry is pumped to a field near the plant site through a portable aluminum pipe. The lime mud settles out of the slurry soon after its discharge on the land and forms a fan shaped deposit. After a suitable deposit of mud has accumulated a joint of the pipe is removed or the pipe is moved and the slurry discharged on fresh ground. This practice was started in the fall of 1954. Only a small portion of the field has been covered to date. It is estimated that 20 to 30 acres per year will be covered with the lime mud deposit. The field being used currently is part of a 160 acre tract. Several hundred acres are available near the plant. The soil in the vicinity tends to be high in clay which makes it difficult to work into seed beds. It tends to form clods and stick to equipment. The lime mud will improve the quality of the soil by making it more workable.

The water draining from the slurry percolates into the ground. It was stated that no runoff to surface drains occurred during last season. Later in the season after the ground becomes saturated, and frozen ground limits percolation, runoff may occur from the area. Such runoff will enter a natural drain called Whitman's Cooley which flows into the Big Horn River at a point above the plant water intake.

Prior to such broad field application the lime cake slurry was discharged to a pond where the mud settled out. The overflow entered the plant outfall. At times in the past the lime cake slurry has been discharged with other plant wastes.

2. Removal of Mud from Flume Water and from Beets

A flight-type drag chain is operated in part of the beet flume to remove mud from the water. The mud is hauled to a dump. This facility removes only the heavier very readily settleable particles.

The beets are screened when elevated to the storage piles in order to remove soil. They are screened again when conveyed from the piles to the plant fluming system. The soil in this vicinity is high in clay content and tends to cling to the beets, making the quantity of soil removed in the screens very high. The soil removed in these screens is collected in a hopper and dumped to the trucks used to deliver the beets. It is returned to the fields.

3. Lagooning of Grate Ashes and Boiler Blowdown

Grate ashes from the boiler house are transported as a slurry to an impounding basin adjacent to the factory. The ash settles out of the slurry. The supernatant water overflow is returned and reused to slurry more ashes. There is no overflow from the pond and little make-up is required. Overflow from the condenser water supply tank is used for make-up. Boiler blowdown is discharged to the ash pit.

The ashes are hauled from the pond during the winter and used for ice control on local roads.

Discussion of Available Waste Control Measures

The methods of reduction of waste loads from beet sugar plants considered to be most economic and practical are discussed below. Most of these measures involve modifications in process or method of operation. Estimates of the effect of each of these measures are listed in Table 2.

Reference is made to three recent articles on pollution from beet sugar plants, reprints of which are attached. These articles are entitled "Industrial Waste Guide-Beet Sugar," a report entitled "Beet Sugar Waste Treatment by Broad Field Application" and an article entitled "Treatment of Beet Sugar Wastes." (One copy each of these reports has been provided the industry.)

1. Impounding of Lime Cake Slurry

The present system as practiced of broad field application of this waste accomplishes complete removal of this waste. The possibility remains that the ground may not absorb the water and a runoff occur. This possibility could be eliminated by construction of low earth embankments at the edges of the field if proven to be necessary.

2. Drying of Pulp

Pulp silo drainage may be eliminated by the pressing and drying of pulp. Pulp press water is created in place of pulp silo drainage but the pulp press water has only about 20% of the quantity of BOD that the silo drainage would have. In addition to a substantial reduction in pollution the drying of pulp has other significant advantages. The costs of shipping pulp are greatly reduced in that elimination of water reduces the weight to be shipped to about 5% of the wet pulp weight. This permits marketing in an expanded area. Malodorous conditions associated with wet storage of pulp are greatly reduced. The particularly objectionable hydrogen sulfide, mercaptan, and such odor associated with putrefaction may be eliminated from beet sugar plant operation. The yield of beet pulp is increased markedly because bacterial decomposition in wet pulp silos may consume major portions of the pulp.

As indicated in Table 2, with the control measure of lime slurry disposal now in operation, the pressing and drying of pulp would reduce the BOD load of the remaining water about 50 percent.

TABLE 2

ESTIMATED EFFECTS OF CONTROL MEASURES

	Flow	BOD, 5-Day 20° C.			Suspended Solids	
	gal/day	ppm	lbs/day	Pounds Per Ton of Beets Processed	ppm	lbs/day
Total Wastes as Produced	5,800,000	990	48,100	26	5,200	252,800
Remaining Wastes with Lime Slurry Impounded (Present Effluent to River)	5,630,000	770	36,100	19.5	1,760	82,800
Remaining Wastes with Lime Slurry Impounded with Pulp Pressed and Dried	5,570,000	390	17,900	9.7	1,800	83,100
Remaining Wastes with Above Two Control Measures in Operation and Pulp Screen and Press Water Recirculated	5,240,000	300	13,100	7.1	1,800	81,900
Remaining Wastes with Lime Slurry Impounded and Pulp Pressed and Dried plus Broad Field Treatment of Remaining Plant Wastes	5,240,000	150	6,600	3.6	-	-

3. Continuous Diffusers and Reuse of Pulp Press Water

Pulp screen and pulp press water wastes are being eliminated at some plants which have continuous diffusers by the practice of returning the pulp press water to the battery supply. Continuous diffusers permit the elimination of pulp screen water when drained pulp is elevated from the diffuser and transported without slurrying to the pulp presses. The pulp screen water is heated to prevent bacterial growth and returned to the battery supply. One plant has practiced the reuse of pulp screen and press water in the batteries of a cell type diffuser.

4. Recirculation of Flume Water

The recirculation of flume water with discharge limited to sludge drawoff has been practiced. Buildup of dissolved solids in the water is controlled by a bleed-off with the slurried sludge. The sludge is pumped to a field where the water content is disposed of by percolation into the soil. Odors in the flume water are controllable by shot chlorination.

Since flume water is actually second use of barometric condenser water, flume water reuse does not reduce the water requirements of the plant unless a recirculated cooling water system is installed for barometric condenser water.

Head losses through the fluming system and settling pond may be held to a very few feet. Recirculation then requires only a low lift.

5. Broad Field Application of Beet Sugar Wastes

Treatment by broad field application as described in the publication referred to in the introductory paragraph of this section may be appropriate to certain wastes or residual wastes of this plant. Experience with this type of treatment has been with total wastes of a straight house plant practicing pressing and drying of pulp. The total wastes of the plant, including lime cake slurry, were applied to the field. It is doubtful that this treatment would be highly effective for pulp silo drainage. The present practice of the Hardin plant in separate broad field application of lime cake slurry without effluent to the stream would be superior to inclusion of this waste with other wastes given broad field application type of treatment. With lime cake slurry out of the picture and pulp silo drainage eliminated by drying pulp wastes to be given broad field application treatment would be

(1) Flume water
(2) Pulp screen water
(3) Pulp press water
(4) Miscellaneous wastes

It is estimated that broad field treatment of these wastes would remove about 50% of the BOD and practically all suspended solids. The estimated remaining BOD load is given in Table 2.

/Sgd/ G. N. McDermott
Sanitary Engineer
Industrial Wastes Studies
WS and WPC Research
Robert A. Taft Sanitary
Engineering Center

APPROVED:

/Sgd/ Glen J. Hopkins
Sanitary Engineer Director

April 3, 1956

YELLOWSTONE RIVER STUDY
AS
RELATED TO HOLLY SUGAR COMPANY
HARDIN, MONTANA

A comprehensive study of waste discharges to the Yellowstone River from above Laurel to below Sidney, and to the Big Horn River from above Hardin to its confluence with the Yellowstone, was made during the period November 7 to 13, 1955. This was done since tastes and odors in downstream water supplies have reached proportions that cannot be controlled with usual water treatment processes.

Twelve grab samples of this industrial waste were collected at 2-hour intervals from approximately 7:00 a.m., on November 10 to 5:00 a.m., November 11, and composited according to flow. Rates and total flow were calculated from heads over a rectangular weir installed a short distance below the waste outlet. Volume of waste discharged to the Big Horn River for the 24-hour period was 4.6 million gallons.

Analytical results are tabulated in Table 3. The pH of the waste varied from a maximum of >9.6 to a minimum of 6.0, with an average of >7.8. Individual grab samples show a wide variation in the type of wastes discharge for short periods of time.

Oxygen consumed was 1,643 parts per million indicative of a waste high in chemical oxygen demand. Biochemical oxygen demand was 624 ppm, for a total discharge of 23,850 pounds. Suspended solids amounted to 2,260 ppm and 86,500 pounds. This is equivalent to 13 pounds of B.O.D. and 48 pounds of suspended solids per ton of beets processed. Pronounced effects of this organic load on the river were evident.

Phenolic compounds were absent in the wastes although present in the raw river water. Quite probably the low concentrations of phenol were destroyed in the plant operations.

Waste temperatures ranged from a maximum of 30° C. to a minimum of 25 for an average 27.7° C.

A comparison of data in Tables 2 and 3 show close relationship for suspended solids, but a wide variation in B.O.D. Estimated suspended solids, without lime slurry, were 82,780 pounds, while calculations from laboratory data indicate 86,500 pounds. B.O.D. was estimated at 36,100 pounds, and measured as 23,850 pounds. Difference in soils, beets, housekeeping and methods of processing all affect the volume and character of wastes. The volume of waste measured was 1 M.G. less than calculated by plant officials.

TABLE 3

YELLOWSTONE RIVER STUDY
NOVEMBER 1955
HOLLY SUGAR COMPANY
HARDIN, MONTANA

	November 10-11
Flow MGD	4.6
pH	
Average	>7.8
Maximum	>9.6
Minimum	6.0
Oxygen Consumed	1,643.7
5-Day 20° C. B.O.D.	
ppm	624
Pounds	23,850
Suspended Solids	
ppm	2,260
Pounds	86,500
Phenol	0.0
Copper	
ppm	0.95
Pounds	36.3
Lead	
ppm	0.09
Pounds	3.44
Temperature °C.	
Average	27.7
Maximum	30.0
Minimum	25.0
Production	
Tons of beets	1,850

Discussion

The history of tastes and odors in water supplies taken from lower Yellowstone establishes their occurrence in the fall or winter months. Thus they coincide with lower water temperatures and the impact of heavy loads of organic material from sugar refineries. The 1955 study of the Yellowstone River and tributaries, including all major sources of pollution, establishes that industrial wastes are discharged in sufficient quantities to provoke taste and odor problems.

Colder water temperatures markedly reduce the rate of oxidation of organic materials at the time when the heaviest load is discharged to the streams. Thus the effects are extended much greater distances. Pollution from this industry via the Big Horn adds to that in the main stem, and zones of pollution are extended still farther downstream. Synergistic effects of sugar refining wastes and other pollutants known to be present appear to be the basic cause of taste and odor problems.

Settling of solids on the stream bed also aggravates the situation. Subsequent digestion and movement of these sludge beds by fluctuating river levels introduces relatively short periods of heavy pollution that increases taste and odor potentialities. The major source of organic solids in the river system is the wastes produced by beet sugar refineries. Although dissolved oxygen content during the week of study was depressed only at isolated points, effects of the heavy organic load on the Yellowstone River were readily visible.

Recommendations

It is recommended that:

1. Improvements be made in waste control as necessary to virtually eliminate floating and settling solids and to reduce 5-day 20° C. B.O.D. to not more than 8 pounds per ton of beets sliced.

2. Effective monitoring and control procedures be established over all plant wastes so none can be discharged without adequate control.

3. A comprehensive plan of pollution control, including a time schedule of installation and construction, be prepared and submitted at the earliest possible date to the Montana State Board of Health for review. As much of the program as possible should be completed prior to the fall of 1956.

/Sgd/ Glen J. Hopkins
Sanitary Engineer Director

RESTRICTED INFORMATION

ATTACHMENT "F"

April 27, 1956

WASTE CONTROL EVALUATION REPORT
HOLLY SUGAR COMPANY
SIDNEY, MONTANA

Prepared by
G. N. McDermott, Sanitary Engineer
Industrial Wastes Studies
WS and WPC Program

At the Request of
C. W. Brinck, Director
Division of Environmental Sanitation
Montana State Board of Health
Helena, Montana

Purpose

This conference and inspection was to obtain information on liquid wastes of the beet sugar plant pertinent to water pollution problems of the Yellowstone River. The information desired included elementary knowledge of the plant processes and waste sources, data on the volume and character of the wastes, and details of water pollution control measures in operation.

Date of Conference

October 21, 1955.

Personnel Participating

HOLLY SUGAR CORPORATION
J. D. Algier, Superintendent

MONTANA STATE BOARD OF HEALTH
C. W. Brinck, Director, Division of Environmental Sanitation

PUBLIC HEALTH SERVICE
Paul Bolton, Public Health Engineer, Water Supply and Water Pollution Control Activities, Kansas City, Missouri
G. N. Mc Dermott, Sanitary Engineer, Robert A. Taft Sanitary Engineering Center, Cincinnati 26, Ohio

PLANT OPERATIONS, FACILITIES, AND PRODUCTION

Summary Description of Operations

This plant employs the standard process of beet sugar refining employed in straight house operation. The Steffen process is not used. The processes of interest to liquid waste production at this plant are beet fluming, continuous diffuser operation, lime purification, and pulp drying. The plant was built in 1925. The continuous diffuser was installed in

97

1948. The pulp dryer was constructed in 1953. Natural gas has been used for boiler heating since 1951. A more detailed description of the processes is given in a subsequent section.

Plant Location

The plant is located at the east edge of Sidney, Montana about two miles north of the Yellowstone River.

Raw Materials

Sugar Beets
Limestone
Coke
Coal
Natural Gas
Sulfur
Soya Bean Oil
Diatomaceous Earth Filter Aid
Carbon
Formaldehyde
Boiler Water Treating Compounds

The rate of processing beets at the plant generally runs between 1850 to 1900 tons per day. On peak days 2000 tons or more may be processed. The average for the 1954 campaign was 1826 and the current rate is about 1850 tons per day.

Products

Sugar
Dry Pulp
Ground Dry Pulp
Molasses

Operating Schedule

The operation is seasonal, generally commencing early in October and lasting about 120 days. Operations are continuous 7 days per week 24 hours per day during the campaign.

Employees

During the campaign approximately 200 employees are required to operate the refinery. During the remainder of the year about 60 people are employed.

Water Supply and Water Treatment

Water for process purposes is obtained from the irrigation canal known as Lateral E. Lateral E diverts water from the Yellowstone River approximately 50 miles above Sidney, Montana. The water is diverted from the ditch and flows by gravity to an open earth reservoir about 80 acres in area located near the plant. Water is obtained direct from the ditch at a rate of about 1000 gpm and from the lake at a rate of about 5000 gpm. No treatment is required. Drinking water is obtained from a gravel packed well about 40-50 feet deep located on the plant property. The well water is not treated.

Nalco Water Treating Compound No. 918, a phosphate compound, is used to treat the battery supply water at the rate of 1-1/2 pounds per 8 hours. In 1954, 2100 pounds of Nalco 7 and 1200 pounds of Nalco 478 were used for boiler water treatment.

Waste Disposal

The liquid wastes of the refinery are discharged without treatment to an irrigation ditch which flows to the south and east and enters the Yellowstone River at a point several miles from the plant.

Sanitary sewage enters the general plant sewer system and is discharged with the process wastes. In the summer the sanitary sewage is diluted in irrigation water in the ditch.

PROCESS DESCRIPTION AND WASTE SOURCES

The process and equipment employed at this plant which are of interest to water pollution are described in the following paragraphs.

Beet Fluming and Washing

As the beets are received they are passed over screens for removal of soil and debris and then stored in stock piles. A considerable quantity of soil, rock, beet tops, tap roots, and debris are received with the beets. The weight of this material may at times be as high as 15% of the beet weight. The tare averages about 7% to 8%. So far this operating season the tare has been running about 5%. The material removed by the screens is hauled to fields. The beets are transported from the stock piles to the process by water flowing in channels referred to as flumes. This water transport acts as a wash to remove much of the loose soil from the beets. Readily settleable mud and rock are removed from the flume water in a sunken section along the floor of the flume.

The beets and flume water are discharged to a beet wheel. The flume water passes through openings in the beet wheel to waste. The beets are retained in pockets on the beet wheel and elevated to the beet washer. The washer is a vat provided with mechanical agitation. Fresh water is added to the washer continuously and overflows to waste with the flume water.

The combined flume and wash water constitutes the first significant liquid waste of the process. It is referred to as flume water waste. Condenser water used to produce a vacuum in the evaporators and vacuum pans is used for part of the flume water supply. Pulp screen and pulp press water, the sources of which are subsequently described, is also used for flume water. Fresh water is used for the remainder of the flume water.

Diffusers

The washed beets are sliced into long narrow ribbons and discharged to diffusers. This plant is equipped with a Silver continuous diffuser of the chain type. The diffuser consists of a series of compartments in a large tank. Fresh battery supply water enters an end compartment and overflows tank to tank to the end of the diffuser. Fresh sliced beets enter at the end at which the raw juice is discharged and are moved from compartment to compartment countercurrent to the flow of extraction juice by flights attached to an endless chain which moves in and out of the compartments. The liquid drawn from the diffusion battery is known as raw juice and contains 10% to 13% sugar plus considerable non-sugars. The spent sliced beets, now called pulp, are lifted from the battery, flushed to a conduit and pumped as a suspension to the pulp drying house. In order to control the growth of bacteria in stagnant corners of the diffuser formaldehyde in the amount of about 50 gallons per day is added continuously to the diffuser.

Company officials report that "the formaldehyde, being an organic chemical of relatively high reactivity, combines with certain of the insoluble non-sugars in the pulp to form non-toxic compounds. Repeated tests have failed to reveal the presence of formaldehyde in either the raw juice or pulp press or pulp screen water."

Pulp Screening and Drying

The pulp is pumped as a water suspension to a dewatering screen at the pulp drying house. The water draining from the pulp on this screen is used for fluming beets. The wet pulp is scroll fed to pulp presses. The pulp presses reduce the moisture content of the pulp to about 85%. The pressed pulp is fed to gas fired rotary kiln type drier. The pulp press water is also used for fluming beets.

The pulp is dried to about 8% moisture and the yield is about 5% dried pulp on beets. A small portion of the dried pulp is ground in a hammermill and sold to a dog food manufacturer.

Juice Purification

The raw juice from the diffusers is given chemical treatment and filtration to remove the suspended matter and non-sugars. Milk of lime, which is produced in a kiln at the plant, is added to the raw juice and carbon dioxide is bubbled through until a certain alkalinity is reached. The precipitate which forms is separated from the juice by sedimentation. The sludge from the settling unit is filtered on drum type vacuum filters and sugar traces rinsed from the filter cake. A diatomaceous earth filtering aid is used. The rinsed filter cake is scraped from the filters, slurried, and flushed to the sewer. The juice is given a second treatment with carbon dioxide and the precipitate removed by means of plate and frame filters. The filter cake is slurried and pumped to the vacuum filter which receives the other lime mud. The powdered carbon is used in the latter filtration step and is discharged with the lime mud.

Evaporation

The filter juice is treated with sulfur dioxide gas to the desired pH level. The juice is then concentrated in multiple effect evaporators and filtered again on plate and frame filters. The filter cake from these filters is disposed of as described previously for other filter cake.

Water is further evaporated from the sugar in vacuum pans until crystallization of the sugar takes place and crystals have grown to the desired size. The sugar crystals are separated from the liquid by centrifuging. The residual syrup is further evaporated and centrifuged a second time and finally a third time. Sugar from the second and third crystallization, being impure, is remelted and returned to the process for recovery in first crystallization. The resulting molasses following third crystallization and centrifuging is marketed.

Vacuum on the evaporators and vacuum pans is produced by cascade condensers discharging through barometric legs. The condenser water is used for fluming beets and for battery supply water. This water is slightly contaminated by entrainment and volatilization of materials in the juices. Soy bean oil in the amount of 3 to 4 gallons per day is used in the multiple effect evaporators for foam control. Condensates from the bodies of the multiple effect evaporators are used for boiler feed water and for washing the filter cake in juice purification.

Miscellaneous Wastes

Miscellaneous wastes of the plant include filter cloth washing, floor and equipment washing, waste from the tare house and boiler blowdown. Formerly ashes from the boilers were disposed of as a water slurry; however, since gas burning facilities were installed in 1951 this waste has not been produced. Wastes from the tare house constitute a considerable volume. Samples of each load of beets are weighed and washed in small spray type washers to determine the tare on the loads delivered to the refinery. All of the miscellaneous wastes are discharged directly to the plant sewer system.

ESTIMATED WASTE VOLUME AND CHARACTERISTICS

Studies of the volume and characteristics of liquid wastes have been made at other beet sugar plants. The data obtained in these studies, together with information on the process used, and production rate of this plant, enable the estimation of waste volumes and characteristics. Table 1 lists our estimate of the volume, BOD, and suspended solids of the component wastes from the Sidney Plant. The values should be considered as only rough approximations. However, they may be useful in planning waste control measures.

TABLE 1
ESTIMATED VOLUME, BOD, AND SUSPENDED SOLIDS IN WASTES OF SIDNEY BEET SUGAR PLANT HOLLY SUGAR COMPANY, SIDNEY, MONTANA*

Waste	Flow gal/day	BOD		Suspended Solids	
		ppm	lbs/day	ppm	lbs/day
Flume Water	5,630,000*	180	8,300	1,700	80,000
Pulp Screen Water	440,000	980	3,600	530	1,900
Pulp Press Water	330,000	1,710	4,800	420	1,200
Lime Cake Slurry	170,000	8,600	12,000	120,000	170,000
Condenser Water	3,700,000	40	1,200	-	-

* Condenser water, pulp screen water, and pulp press water are used for flume water together with some fresh water. The flume water volume figure includes the wastes but the figure for BOD and suspended solids are estimates of the amount of material added by the beet fluming operation.

WATER POLLUTION CONTROL PROGRAM

Water pollution control measures applicable to a beet sugar plant include (1) so-called "in-plant" control methods which include changes in operation process or equipment which reduce the waste loads and (2) waste treatment. Both of these types of control measures are included in the following discussion.

Waste Control Measures in Operation

1. Drying of Pulp

Pulp silo drainage has been greatly reduced at this plant by the pressing and drying of pulp. The pulp silo is still in existence and is used for receiving wet pulp when the driers are out of operation for repairs. Pulp press water is created in place of pulp silo drainage but the pulp press water has only about 20% of the quantity of BOD that the silo drainage would have. In addition to a substantial reduction in pollution the drying of pulp has other significant advantages. The great weight reduction decreases the cost of hauling or shipment, malodorous conditions associated with wet storage of pulp are greatly reduced, and the yield of beet pulp is increased markedly because bacterial decomposition in the pulp silo may destroy major portions of the pulp.

2. Removal of Mud from Flume Water and From Beets

A mechanism is operated in the beet flume to remove mud and rocks on the floor of the flume. This facility removes only the heavier very readily settleable particles. The beets are screened when elevated to the storage piles in order to remove soil from them. These measures tend to reduce the quantity of material which ultimately might be contained in the flume water waste if it were not removed.

3. Elimination of Grate Ashes

One waste from beet plants may be grate ashes from the boiler house. Such ashes are usually disposed of by slurrying them with water. This slurry may be sewered but is usually pumped to a settling pond. Frequently the overflow is sewered and in cases it is recirculated and the liquid waste eliminated. Replacement of coal fuel by gas eliminated the production of ashes at this plant.

4. Land Disposal

In 1947 and 1948 the wastes of the plant were diverted by some farmers from the ditch carrying the wastes to the river to farm land. The suspended material in the waste settled out on the land which improved the quality of the soil. In 1949 a controversy developed between the farmers using the waste and owners of adjacent land. The owners of the adjacent land were reported to object to such use of the wastes because the practice raised the water table in the vicinity and damaged their land. The practice was stopped in 1949. In 1954 some waste was used in this manner. None was disposed of in this manner during the 1955 campaign. Apparently the land on which the wastes were used permitted complete infiltration of the wastes at least part of the time.

Discussion of Available Waste Control Measures

The methods of reduction of waste loads from beet sugar plants considered to be most economical and practical are discussed below. Estimates of the effect of each of these measures on some important characteristics of the wastes are listed in Table 2.

Reference is made to two recent articles on pollution from beet sugar plants, reprints of which are attached. These articles are entitled "Industrial Waste Guide-Beet Sugar," and a report entitled "Beet Sugar Waste Treatment by Broad Field Application." (One copy each of these reports has been provided the industry.)

1. Impounding of Lime Cake Slurry

The impounding of lime cake slurry is practically a universal practice in the industry. These impoundments may be of sufficient volume as to provide for storage of the entire lime slurry output for the campaign with the water content eventually infiltrating into the soil or evaporating. In cases, broad field application of the waste is practiced so that the lime settles out on the field and the water seeps into the ground without the necessity of any dams or banks. In cases where low lying land is selected for the impoundments, the land is thereby built up and its quality improved. It has been reported that where the land is a heavy clay the lime waste will make the soil more workable and have less tendency to form into clods.

In other lime slurry impounding installations the impoundment volume is such that some overflow occurs. The suspended material settles out in the pond. The overflow is much less objectionable in a receiving stream than are the unsettled waste. The lime accumulating in these ponds is marketed as a fertilizer or soil conditioning agent in some areas.

2. Continuous Diffusers with Reuse of Pulp Press Water

Pulp screen and pulp press water wastes are being eliminated at some plants which have continuous diffusers. The pulp screen water waste is eliminated by obtaining the pulp in a drained state from the diffuser and transporting it in the moist state to the pulp presses. This precludes the practice of diluting the pulp to a slurry and pumping it to a screen in the drying house. The pulp press water is returned to the diffuser as part of the battery supply water. It is heated to prevent bacterial growth. In addition to reducing pollution such practice is believed to accomplish some increase in sugar recovery.

TABLE 2

ESTIMATED EFFECTS OF CONTROL MEASURES

		BOD, 5-Day 20° C.			Suspended Solids	
	Flow gal/day	ppm	lbs/day	Pounds Per Ton of Beets Processed	ppm	lbs/day
Total Wastes as Produced (Present Effluent to River)	5,800,000	618	29,900	16.1	5,170	250,000
Remaining Wastes with Lime Slurry Impounded	5,630,000	382	17,900	10.3	1,700	80,000
Remaining Wastes with Lime Slurry Impounded Pulp Screen Water and Pulp Press Water Eliminated	5,630,000*	200	9,500	5.1		77,000
Remaining Wastes with Lime Slurry Impounded, Pulp Screen Water and Pulp Press Water Eliminated, and with Remaining Waste Given Broad Field Treatment	5,630,000*		4,750	2.6		

*Assume fresh water would be used in beet fluming in place of volume of pulp screen and pulp press water.

3. Recirculation of Flume Water

The recirculation of flume water through a settling basin has been practiced with practically complete elimination of the waste. Build-up of dissolved solids in the water is controlled by a bleed-off with the slurried sludge. The sludge slurry is pumped to a field where the water content is disposed of by percolation into the soil. Odors in the flume water have been reported as controllable by shot chlorination. Since flume water is principally a second use of barometric condenser water, flume water reuse does not reduce the water requirements of the plant unless a recirculated cooling water system is installed for barometric condenser water.

Head losses through the fluming system and settling pond may be held to a very few feet. Recirculation then requires only a low lift.

4. Broad Field Application of Beet Sugar Wastes

Treatment by broad field application as described in the publication referred to in the introductory paragraph of this section may be appropriate to the wastes or residual wastes of this plant. Experience with this type of treatment has been with total wastes of a straight house plant practicing pressing and drying of pulp which is very similar to the Sidney Plant. The total wastes of the plant, including lime cake slurry, were applied to the field. The impoundment of lime cake slurry, and elimination of pulp screen and pulp press water and broad field treatment of the residual wastes would be more effective in reducing the waste load than broad field treatment of the total combined wastes. With lime slurry impounded and pulp screen water and pulp press water eliminated, the residual wastes to be given broad field treatment would be: (1) flume water and (2) miscellaneous wastes. It is estimated that broad field treatment of these wastes would remove about 50% of the BOD and practically all suspended solids. The estimated remaining BOD load is given in Table 2.

5. Screening of Wastes

Screening of waste waters to remove pulp, leaves, rootlets, and debris from the wastes is practiced on total wastes at some plants. Screening of pulp screen water and pulp press water by means of fine (30 x 40 mesh) vibrating screens is practiced at some plants for the recovery of pulp. It has been reported that 2.5 pounds of pulp (dry basis) per ton of beets may be recovered from pulp screen water by such practice and an estimated 7 to 10 pounds from pulp press water.

/Sgd/ G. N. McDermott
Sanitary Engineer
Industrial Wastes Studies
WS and WPC Research
Robert A. Taft Sanitary
Engineering Center

APPROVED:

/Sgd/ Glen J. Hopkins
Sanitary Engineer Director

May 4,1956

YELLOWSTONE RIVER STUDY
AS
RELATED TO HOLLY SUGAR COMPANY
SIDNEY, MONTANA

During the period of November 7 to 13, 1955, a comprehensive study of the lower 360 miles of the Yellowstone River and 41 miles of the Big Horn River was made to ascertain source/s of pollution causing severe tastes and odors in water supplies using Yellowstone and Missouri River water as a source. The Williston, North Dakota, municipal water supply has been affected by pollution, as have the supplies of several communities in Montana. Taste and odor problems have always occurred during the period of operation of the beet sugar industry.

Analytical data resulting from 24-hour composite samples collected from 7:00 a.m., November 10, to 5:00 a.m., November 11, at this industry are shown in Table 3. Quantity and characteristics compare closely with stream data obtained during the same period.

The volume of waste discharged calculated from head over a rectangular weir, was 7.2 M.G., approximately 1.4 million gallons more than estimated. The pH varied from 9.5 to 8.0.

Oxygen consumed analyses indicate a waste strong in chemical oxygen demand. This is confirmed by a biochemical oxygen demand of 444 parts per million or 26,600 pounds for the day. The samples were collected some distance below the plant outlet and some of the immediate demand may have been exerted prior to sample collection. A suspended solids content of 3,600 ppm or 216,000 pounds establishes the large quantity of solids discharged.

B.O.D. and suspended solids are 13.5 pounds and 110 pounds per ton of beets sliced, respectively. These results compare quite favorably with evaluated data in Table 2, which also sets forth expected reductions by appropriate waste control measures.

Waste temperatures ranged from 24° C. to 13.5° C. for an average of 17.8° C.

Discussion

The history of tastes and odors in water supplies taken from lower Yellowstone establishes their occurrence in the fall or winter months. Thus they coincide with lower water temperatures and the impact of heavy loads of organic material from sugar refineries. The 1955 study of the Yellowstone River and tributaries, including all major sources of pollution, establishes that industrial wastes are discharged in sufficient quantities to provoke taste and odor problems.

TABLE 3

YELLOWSTONE RIVER STUDY
NOVEMBER 1955
HOLLY SUGAR COMPANY
SIDNEY, MONTANA

	November 10-11
Flow MGD	7.2
pH	
Average	9.1
Maximum	9.5
Minimum	8.0
Oxygen Consumed ppm	1,056.7
5-Day 20° C. B.O.D.	
ppm	444.0
Pounds	26,600.0
Suspended Solids	
ppm	3,600.0
Pounds	216,000.0
Phenol	
ppb	3.0
Pounds	0.18
Copper	
ppm	0.16
Pounds	9.6
Lead	
ppm	.02
Pounds	1.20
Temperatures °C.	
Average	17.8
Maximum	24.0
Minimum	13.5
Production	
Tons of beets	1,961

Colder water temperatures markedly reduce the rate of oxidation of organic materials at the time when the heaviest load is discharged to the streams. Thus the effects are extended much greater distances. Synergistic effects of sugar refining wastes and other pollutants known to be present appear to be the basic cause of taste and odor problems.

Settling of solids on the stream bed also aggravates the situation. Subsequent movement of these sludge beds by fluctuating river levels introduces relatively short periods of heavy pollution that increases taste and odor potentialities. The major source of organic solids in the river system is the wastes produced by beet sugar refineries. Although dissolved oxygen content during the week of study was depressed only at isolated points, adverse effects of the heavy organic load on the Yellowstone River were readily visible.

Recommendations

It is recommended that:

1. Improvements be made in waste control as necessary to virtually eliminate floating and settling solids and to reduce 5-day 20° C. B.O.D. to not more than 8 pounds per ton of beets sliced.
2. Effective monitoring and control procedures be established over all plant wastes so none can be discharged without adequate control.
3. A comprehensive plan of pollution control, including a time schedule of installation and construction, be prepared and submitted at the earliest possible date to the Montana State Board of Health for review. As much of the program as possible should be completed prior to the fall of 1956.

/Sgd/ Glen J. Hopkins
Sanitary Engineer Director

RESTRICTED INFORMATION

May 8, 1956

ATTACHMENT "G"

WASTE CONTROL EVALUATION REPORT

MIDLAND EMPIRE PACKING COMPANY

BILLINGS, MONTANA

Prepared by
Department of Health, Education, and Welfare
U. S. Public Health Service, Region VI
Water Supply and Water Pollution Control Activities

At the request of Montana State Board of Health

Purpose

The conference and inspection was conducted to obtain information on wastes from the packinghouse as related to pollution problems in the Yellowstone River. Desired information included basic knowledge of plant processes, existing waste control measures, and an estimate of the volume and strength of wastes discharged at this industry.

Date of Conference

January 26, 1956

Personnel Participating

Midland Empire Packing Company
    C. P. Shaeffer - President and Co-owner
    C. R. Crosser - Secretary-Treasurer and Co-owner

Montana State Board of Health
    Peter Breysse - Engineer

Public Health Service
    Paul Bolton - Public Health Engineer

Plant Operation Facilities and Production

Plant Location

The plant facilities are located east of the city limits of Billings on the north bank of Yegen Drain, approximately a northeast extension of Minnesota Avenue and south of the Midland Empire Fairgrounds.

Operating Schedule

Plant operations are on a year-round schedule of 8 hours per day, 5 days per week.

Raw Materials

Cattle - 50 head per day - 750# each - morning kill
Hogs - 125 head per day - 240# each - afternoon kill
Calves - 25 to 30 head per month

Turco "Active" - for washing smokehouses, tables, floors, etc.
Tri-sodium Phosphate - washing tripe and equipment

These materials are used for curing.
Presco - 94#/week - Preservaline Mfg. Co., Flemington, N.J.
or
Mayers - 85#/week - Mayers Co., Chicago, Ill.

Equal volumes of salt.

Products

1. Beef and beef products
2. Processed pork - hams, bacon, sausage, smoked and cooked meats, wieners, etc.
3. Lard - 1, 2, 4# packages
   4, 8# pails
   50# cans
   420# tierces
4. Inedible grease and tallow - tank car lots
5. Tankage - 100# bags
6. Hides

Employees

From 70 to 75 persons are employed.

Brief of Plant Operations

Cattle, hogs, and a few calves are processed at this plant. Cattle are either shot or stunned, stuck, hoisted to bleed, and the head removed. The carcass is then dropped to a positioning, metal frame "bed" for hide removal. The animal is opened and organs removed. Paunches are placed on a table, the pecks removed for hog feed, and the stomach and intestines are opened and the contents flushed to the sewer. Edible sections of the stomach are removed and the intestines processed into tankage. After halving, carcasses are sent to an overnight cooler for chill and then to a storage cooler.

Hogs are shackled, hung on a rail, and stuck. The animal is then scalded at approximately 150°F., dehaired mechanically, singed, washed, shaved, opened up, the organs removed, and rewashed. The carcass and organs are then processed. Edible and inedible portions are processed into finished form.

Lard is rendered in an open kettle. Leaf lard is processed as rapidly as produced, however other fats from trimming operations may accumulate for 12 to 24 hours. The kettle is steam jacketed with an open top. During the two hours of cooking, water boils off to the atmosphere. Lard is put into an agitator and cooled to packaging temperature. Rinds are sent to tankage.

Wieners are colored, and as other meats requiring seasoning, are seasoned in vats. Cooked hams are boiled. Hams, large bologna, bacon, butts and other smoked meats are cooked in the smokehouse. Picnic hams are pickled by submergence in a prepared solution.

Bones, floor sweepings and similar materials are sent to the tank room for tankage. Tallow and greases rendered from tank materials are pumped to storage and sold in tank car lots. Solids from inedible rendering are pressed, ground and sacked in 100 lb. bags.

Hides are salted and stored in the hide cellar for approximately three months prior to sale.

Plant Facilities

Plant facilities consist of the processing building and animal pens. Cattle pens consist of ten acres back of the building and five acres a short distance upstream. The five-acre tract has concrete areas around the feed bunks. A one-acre earthen bottom holding pen is available for hogs. Farmers haul away cattle droppings, but hog pens are not cleaned.

Water Supply

Water for all purposes is purchased from the municipal supply. Purchases for October, November and December 1955 were 1,764,750, 2,073,000 and 2,373,000 gallons respectively. Based on estimated calendar days of operation this gives an average daily use per month of 84,036, 103,650, and 113,000 gallons.

Waste Disposal

Sanitary sewage is discharged without treatment to Yegen Ditch. A recent fire at the plant disrupted the use of sanitary facilities. A pit privy was constructed over Yegen Drain for use until new facilities were completed. The privy is still in existence.

Liquid wastes from operations flow by gravity or are lifted by pumps and ejectors to an outfall line discharging into Yegen Drain just below the sanitary sewer.

Studies of volume and characteristics of liquid wastes have been completed at numerous packing plants. Data obtained from these studies together with information on processes and production rate of this plant enable estimation of pollutional qualities of liquid wastes. The following tabulation sets forth estimated characteristics based on a mixed kill of 67,500# per day live weight. Housekeeping practices, reclamation and salvage cause wide variations in sewered losses among plants. These estimates are thus intended only to establish the general range of wastes and should not be used for design of treatment facilities. Actual design should be based on information obtained from analyzing several composite samples of plant wastes covering periods of daily operations.

	5-day 20°C B.O.D.			Suspended Solids			Grease		
Av. Flow Gallons per day	#/1000# live wt.	#/day	ppm	#/1000# live wt.	#/day	ppm	#/1000# live wt.	#/day	ppm
100,000	17	1,149	1,376	9	607	730	1.5	101	121

The quantity of pollution discharged is readily realized when compared to domestic contributions. The 1,149 pounds of B.O.D. estimated from the daily mixed kill is equivalent to the organic wastes of 6,894 persons.

Waste Control

No waste control measures are practiced at this plant other than those described as part of operations whereby normal procedures of manufacture of products or byproducts automatically provide a limited effect in reducing waste discharges.

River Pollution

A comprehensive study of waste discharges to the Yellowstone River from above Laurel to below Sidney, and to the Big Horn River from above Hardin to its confluence with the Yellowstone, was made during the period Nov. 7 to 13, 1955. Taste and odors in water supplies using the lower Yellowstone River, and the Missouri River immediately below its confluence, have reached an extent that can no longer be tolerated or controlled by usual water treatment methods. A study of these occurrences, the pollution discharged to the Yellowstone, and the effects thereon implicates the untreated discharge of industrial wastes as the causative agent.

Packinghouses contribute grease, high solids and organic loadings, which interfere with the production of safe and palatable water supplies. Grease and solids cause mechanical difficulties in water treatment plants. Partial digestion of sludge banks and subsequent movement downstream imparts objectionable taste and odors to processed water. Blood and other organic materials in solution exert a heavy oxygen demand on the stream water, and in combination with other wastes, produce synergistic actions

112

which intensify the taste and odor producing potential of other pollutants. The estimated population equivalent of about 7,000 persons indicates a sizable contribution by this industry to over-all pollution discharge to the river from the Billings area.

Recommended Waste Control Measures

Based on the information obtained during the plant study and the Yellowstone River survey, it is recommended that:

1. A thorough study of each department of the plant be made to minimize both the volume and nature of materials discharged to the sewer. Especial care should be given to all killing and processing operations. Blood should be collected and utilized in by-products. Grease and meat particles should be salvaged carefully prior to washdown operations.

2. Paunch manure and the contents of intestines be precluded from the plant sewer. Flushing this material to the sewer adds greatly to the suspended solids content and the strength of the waste.

3. Grease removal facilities be installed to efficiently remove grease from plant wastes. Adequate grease and solids removal will facilitate efficient operation of this facility.

4. All wastes from the plant, excluding sanitary sewage, be screened with fine screens so constructed as to prevent escape of solids to the plant sewer.

5. Arrangements as necessary be made to discharge residual wastes and sanitary sewage to the municipal sewer system.

6. A comprehensive plan of pollution control, including a time schedule for installation and construction, be prepared and submitted to the Montana State Board of Health at the earliest possible date. As much of the program as possible should be completed prior to the fall of 1956, in order to reduce the problem of tastes and odors in downstream water supplies.

/s/ Glen J. Hopkins
Sanitary Engineer Director

RESTRICTED INFORMATION

113

ATTACHMENT "H"

May 8, 1956

WASTE CONTROL EVALUATION REPORT
PIERCE PACKING COMPANY
BILLINGS, MONTANA

Prepared by
Department of Health, Education, and Welfare
U. S. Public Health Service, Region VI
Water Supply and Water Pollution Control Activities

At the request of
Montana State Board of Health

Purpose

This conference and inspection was to obtain information on wastes pertinent to water pollution problems of the Yellowstone River. The information desired included general knowledge of the plant operations, waste control practices, and the volume and character of the wastes discharged by the industry.

Date of Conference

January 26, 1956.

Personnel Participating

Pierce Packing Company
    Frank J. Schuster - Superintendent
    Keith Markegard - Chief Engineer

Montana State Board of Health
    Peter Breysse - Engineer

Public Health Service
    Paul Bolton - Public Health Engineer

Plant Operation, Facilities, and Production

Summary Description of Operations

This plant employs the standard processes for supplying fresh meats. No canning operations are done. Cattle are dressed out, halved and some are quartered. Hogs are dressed out and processed into hams, bacon, wieners, bologna and the various other marketable products. Smoking and cooking equipment are used. Lard is rendered and packaged. Inedible products are fats sold in carload lots, hides, and tankage. Liquid wastes are discharged to the plant sewer. Certain unutilizable solids are hauled to the municipal dump. Cattle pecks, including the contents, are separated and used for hog feed.

Plant Location

The plant facilities are located in the east part of Billings on the north side of the Northern Pacific Railroad tracks. North 15th Street, and North 13th Street bound the area on the east and west, and North 14th Street ends at the north side.

Raw Materials

Raw materials utilized in processing are as follows:

Hogs 700 head per day on Monday, Wednesday and Friday.
Cattle - 140 head per day on Tuesday and Thursday.

Cleaning Materials:
Tri-sodium phosphate - 200 pounds per week for washing floors.
ByTex 13 - 200 pounds per week for cleaning and laundry of work clothing.
SuTex - 50 pounds per week) Detergents for smokehouse and
MetaTex - 25 pounds per week) trolley cleaning.

The above materials are Birko-chemicals procured from the Birkenwald Company in Seattle, Washington.

Curing and Pickling Materials:
Corn sugar - one ton per week.
Beet sugar - one ton per week.
Nitrate)
Nitrite) - 10 pounds per week.
Sodium chloride - one ton per day.

Various seasonings.

Products

A complete line of fresh, cooked, smoked and pickled meats and steam rendered lard. No canning is done. Inedible products are hides, fats and tankage.

Operating Schedule

The operation is year-round usually on an 8-hour, 5-day per week schedule. Lard rendering operations are carried over into Saturday as a result of Friday's hog kill. The kill is fairly even throughout the year, however from April to September two hours per week may be added to the cattle kill and in the fall three hours per week on the hog kill.

Employees

One hundred and eighty people are employed by the packing company.

Water Supply

Water for the plant is purchased from the city of Billings; 6,775,500 gallons and 5,034,500 gallons were purchased for the months of November and December, respectively. Based on 20 working days in November and 21 in December, the average daily water use for each month is 338,780 gallons and 239,738 gallons.

Waste Disposal

Liquid wastes, including the sanitary sewage from the plant, are discharged in a separate sewer to Yegen Drain, a short distance to the southeast. It was reported that large quantities of grease accumulate in the manholes on the line. These grease accumulations are removed once per month. The sewer outlet appears to be below the water level in Yegen Drain and causes the water level in the manholes to rise above the crown of the sewer. Floating grease thus accumulates in the manholes. Large accumulations of grease were noted at the outlet. Some chunks were 12 to 14 inches long, up to two inches thick and semicircular in form from breaking loose after accumulating on the sewer surfaces. It was obvious that a heavy pollutional load is discharged to the receiving ditch.

Waste solids materials are hauled to the municipal dump.

Process Description and Waste Sources

The processes and equipment employed in the processing of meats are quite varied and numerous. Many of the individual processes have a continuous or intermittent waste discharge, all of which contribute to water pollution. Only the major sources are discussed in the following sections.

Killing and Preparatory Operations

Cattle are stunned with a sledge, shackled, hung, and stuck for bleeding. Older animals or those with heavier heads are shot rather than stunned. The carcass is bled in a separate section of the kill floor and the head removed. The bleeding room is curbed on the open side to collect the blood for drying. As the animal moves out of the bleeding room some blood is carried to the dressing area. After bleeding, the animal is lowered to one of two beds for removal of the hide. The "beds" are metal frames for supporting the animals in a convenient position for skinning. Following skinning the animals are rehung for processing.

Hogs are shackled and raised to the sticking position by a wheel. The animals are stuck and bled in a space similar to cattle. The blood drains to a sewer for drying. A second sewer is in the area for disposal of the cleanup waters. After bleeding, the hogs are scalded in a vat, mechanically dehaired, singed, shaved and washed. The singeing and washing is accomplished by automatic controls. The hair is discharged from the dehairing machine into mechanical buggies and subsequently hauled to the municipal dump. Following these preparatory operations the carcass is processed.

Inedible Materials Handling

As previously described, the blood is dried. The drying is completed under vacuum controlled by vacuum pumps. It is then screened and sent to the millhouse for sacking.

Cattle paunches are opened and the paunch manure flushed to the sewer.

Intestines and other meat particles including floor cleanings are washed in a rotary screen and sent to cookers for tankage.

Bones and other hard particles are ground and discharged to the cooker for tankage.

The residue from the rendering of lard is drained to a lower floor. The liquid flows to the sewer and the rinds are shoveled into carts for adding to the cooker for tankage.

Fats resulting from inedible rendering are sold and the solids processed into tankage.

Hides are salted and stacked in the hide cellar. They are sold approximately every three months. Small amounts of liquids flow from the stacks to the sewer system.

Edible Materials Handling

Wieners are hung on trees and cooked in a Jordan cooker. The unit is equipped with a recirculating system for recirculating a vegetable dye for adding color to the product. The cooking temperature is 140° F. Hams and similar cooked meats are prepared in tank type cookers at a temperature of 190° F. The major wastes from these units are the nightly washup and cleaning operations. The trees for transporting and smoking meats are washed with a caustic solution of SuTex. This is a recirculating process re-using the solution. The solution is dumped to the sewer when the density becomes too great for recirculating due to the buildup of pollutants.

Hams, bacon, etc., are cured in the pickle cellar. The wastes are the spills from curing and pickling operations, the dumping of pickling tierces and cleanup operations.

Lard rendering tanks are charged with fats. Water is run through the vats until charged with approximately 4,500 pounds. The tanks are then steamed for three hours and cooked for three hours. The lard is cooled over rolls and packaged. Packages range from one pound to 50-pound tierces.

Stock Pens

Stock pens are available for stock retention. Up to 1,000 head of hogs may be held in an area approximately 100' x 200'. About 50 head of cattle are the maximum held. The cattle area is 100' x 150'. All animal pens have concrete floors and a major part of the areas are covered. The pens are reportedly all drained. The major wastes from holding pens are urine from the animals and surface runoff during periods of wet weather.

Estimated Waste Volumes and Characteristics

Studies of packinghouse wastes have been extensively carried out at numerous plants over the past years. The individual operations within the plant, housekeeping, and consciousness of the heavily polluting qualities of the wastes cause wide variations from plant to plant. Data obtained from other studies as applied to the operations of this plant give the following estimates of wastes. The estimates are based on 240 pound hogs and 740 pound cattle, or an average kill on alternate days of 168,000 and 103,600 pounds.

Hog Kill

Flow gallons per day	#/1000# live wt.	#/day	ppm	#/1000# live wt.	#/day	ppm	#/1000# live wt.	#/day	ppm
360,200	15	2,520	840	7	1,176	392	3.0	504	168
Cattle Kill									
186,400	21	2,176	1,395	15	1,554	1,000	1.0	104	67

It is cautioned that these estimates establish only the general range of wastes and should not be used for design of treatment facilities. Actual design should be based on data obtained from analyzing several composite samples of the plant wastes covering periods of daily operation.

The quantity of pollution discharged is readily realized when compared to domestic contributions. The 2,520 pounds of B.O.D. estimated from pork operations daily is equivalent to the organic wastes of 15,120 persons.

Water Pollution Control Measures

Blood Collection

Blood collection and drying is a strong measure in waste control. Blood is extremely high in biochemical oxygen demand and its salvage effects a substantial reduction in pollutional materials.

Floor Drain Traps

All departments are equipped with grating covers over floor drains. The drains are also equipped with cups with drilled openings for liquid outlet. The openings in the gratings and cups are large enough to pass materials that are not measured in standard analytical procedures but do withhold sizeable particles. However, proper maintenance and cleaning of the drains does assist in pollution control and adds to byproduct recovery.

Grease Recovery Basin

A grease recovery basin 30' long and 15' wide with approximately a 4' water depth is located at the rear of the processing building. Vertical inlets from overhead admit the waste. The basin is dissected longitudinally, causing the wastes to flow twice the length of the unit prior to discharge. The outlet is an elbow which acts as a baffle to inhibit the escape of floating solids. Sewers carrying paunch manure and sanitary sewage bypass the grease recovery basin, but join the common outfall sewer.

Grease and floating materials are skimmed from the basin daily and rendered for tankage. Bottom settlings are removed at the same time and hauled to the city dump.

Outlet Manholes

Cleaning of the manholes on the outfall sewer, if accomplished routinely and often, effect some reduction in pollution discharge. At the same time this gives mute testimony as to the gross inefficiency of the grease removal basin.

River Pollution

Water supplies with sources from the lower reaches of the Yellowstone River and the Missouri River immediately below its confluence have encountered recurring taste and odor problems during the past years. They are now reaching the proportions as to be no longer tolerable or controllable with usual water treatment methods. Association of the problem with pollution in the Yellowstone activated a study of pollution discharged to and the effects on the river water. This study strongly implicates the discharge of industrial wastes as causative agents.

Packing houses contribute grease, high solids and organic loadings, all of which will interfere with production of safe and palatable water supplies in sufficient quantities. Grease and solids may float and cause mechanical difficulties in water treatment or settle out on the stream bottom. Subsequent digestion and movement of these sludge banks may impart objectionable tastes and odors. Blood and other organic materials, in solution form, exert an oxygen demand on stream water and in combination with other wastes may produce a synergistic action intensifying taste and odor imparting qualities of other pollutants. The estimated population equivalent, 15,120 persons, indicates a sizeable contribution by this industry to the over-all pollution discharged to the river from the Billings area.

Recommended Waste Pollution Control Measures

In view of the information obtained during this survey, it is recommended that:

1. A thorough study of each department of the packing plant be made to minimize both the volume and nature of materials discharged to the sewer. Especial care should be given to the killing and processing operations to minimize loss to the sewers of blood, grease and meat particles. These should be salvaged carefully prior to washdown operations. It is desirable to install fine screens on all floor drains, locked in place, until after the sweep-up is completed.

Recommendations 2 and 3 are prerogatives of the industry, as are any in-plant controls, but are included to encourage the most economical method of handling these sources of strong wastes since large quantities of suspended solids and organic matter are added to plant wastes and only partly removed by preparatory units such as fine screens and grease basins.

2. Paunch manure be precluded from the plant sewer. The practice of flushing this material to the sewer system adds greatly to the suspended solids content and the strength of the waste.

3. Dry rendering of lard be employed, or that the residue from steam rendering be evaporated and added to the tankage.

4. Efficient grease removal facilities be installed to receive all waste containing grease. Adequate grease handling equipment will facilitate efficient recovery and assure good operation. Provisions should also be made for removing settleable material.

5. The total wastes from the plant (excluding sanitary sewage) be screened with fine screens so constructed as to prevent solids escaping to the plant sewer.

6. Arrangements be made as necessary to discharge screened wastes and sanitary sewage to the municipal sewer system.

7. Catch basins or screens for solids retention be installed as necessary on drain lines from the stock pens, and properly maintained at all times. The effluent of the basins should be discharged to the plant sewer.

8. A comprehensive plan of pollution control, including a time schedule for installation and construction, be prepared and submitted to the Montana State Board of Health at the earliest possible date. As much of the program as possible should be completed prior to the fall of 1956 in order to reduce the problem of tastes and odors in downstream water supplies.

/Sgd/ Glen J. Hopkins
Sanitary Engineer Director

ATTACHMENT "I"

~~RESTRICTED INFORMATION~~

WASTE CONTROL EVALUATION REPORT
FARMERS UNION CENTRAL EXCHANGE
PETROLEUM REFINERY, LAUREL, MONTANA

Prepared by
G. N. McDermott, Sanitary Engineer
Industrial Wastes Studies
WS and WPC Research

At the Request of
C. W. Brinck, Director
Division of Environmental Sanitation
Montana State Board of Health
Helena, Montana

Purpose

This conference and inspection was to obtain current information on liquid wastes of the refinery pertinent to water pollution problems of the Yellowstone River. The information desired included elementary knowledge of the refining process and waste sources, data on the volume and character of the wastes, and details of water pollution control measures in operation.

Date of Conference

October 19, 1955.

Personnel Participating

FARMERS UNION CENTRAL EXCHANGE PETROLEUM REFINERY
Mr. C. A. Cromwell, General Superintendent
Mr. W. E. Maham, Maintenance Engineer
Mr. O. M. Vadnais, Assistant Superintendent

MONTANA STATE BOARD OF HEALTH
Mr. C. W. Brinck, Director, Division of Environmental Sanitation

PUBLIC HEALTH SERVICE
Mr. Paul Bolton, Public Health Engineer, Water Supply and Water Pollution Control Activities, Kansas City, Missouri
Mr. G. N. McDermott, Sanitary Engineer, Robert A. Taft Sanitary Engineering Center, Cincinnati 26, Ohio

REFINERY OPERATIONS, FACILITIES, AND PRODUCTION

Summary Description of Refinery Operations

The equipment and processes of this refinery are typical of the standard oil refining processes for obtaining products used as motor fuels, heating fuels and asphalt. Separation and purification of constituents of crude oil and conversion of some compounds into those of greater demand is accomplished by the following processes: primary distillation (atmospheric and vacuum), thermal cracking, catalytic cracking, and polymerization. The unit processes and waste sources are discussed in greater detail in a subsequent section.

Refinery Location

This refinery is located approximately 1/2 mile south of the Laurel business section on the west side of U. S. Highways 12 and 310. The tank farm is also located on the west side of the highways. The propery consists of approximately 50 acres on the west side of these highways and roughly 150 acres on the east side. The plant proper is located about 1/2 mile north of the Yellowstone River.

Raw Materials

After October 1955 crude oil processes by the refinery will come from the following sources:

Northwest Sumatra Area in Montana	1/3 of supply
Wyoming black crudes	2/3 of supply

Processing of oil from the Glendive Field, Williston Basin, in eastern Montana was discontinued in October 1955.

The Wyoming crude is a low gravity, asphalt-base crude containing approximately 2% sulfur. The Sumatra crude is of lower sulfur content. The salt content of these crudes is low, one to two pounds per thousand barrels.

Other materials, of interest to water pollution, used by the refinery are as follows:

Caustic Soda
Ammonia
Sulfuric Acid
Copper Chloride
Elemental Sulfur
Litharge
Tetraethyl Lead
Silica aluminum catalyst
Sodium Aluminate
Alum
Calcium Hydroxide
Phosphoric acid catalyst
Diethanolamine
Sodium Sulfide
Vinyl Resin
Bentonite
Fullers Earth
Attapulgus Clay
Tannin
Trisodium phosphate
Chlorine
Soda Ash

Products

Products of this refinery are:

Gasoline, 4 grades
Kerosene
Farm Fuel
No. 1 Fuel Oil
Diesel Oils, No. 1 & 2
Light industrial fuel oils down
    to No. 6 fuel oil
Road oils, three grades
Emulsified asphalt
Penetration asphalts
Propane

Capacity

The rate of processing of crude oil in November 1955 was expected to average 13,550 barrels (42 gallon) per on-stream day.

A program is currently under way to increase capacity up to 17,000 barrels per day. This program includes construction of a new furnance, installing new pumps, and increasing capacity of cooling equipment. It was expected to be completed by April 1, 1956.

Operating Schedule

The principal operations of the refinery are continuous, 24 hours per day, 7 days per week. Some product treating operations are batch type and batches of spent chemicals are discharged intermittently. Such batches are discharged to earth impoundments and not to the sewers so that the wastes discharged to the sewers are relatively uniform.

Each of the three main units of the plant are shut down for cleaning and maintenance purposes on a yearly schedule. Ordinarily this is done in the fall but this year shutting down of the cat cracker has been postponed until spring. Cat cracker shutdown will be scheduled for each spring in the future.

Water Supply and Water Treatment

Process water is pumped from Yellowstone River. The water is treated by coagulation and sedimentation for turbidity removal and chemicals are added for corrosion and algae control. Water is supplied at the rate of about 1200 gallons per minute.

The use of fresh water is reduced considerably by making use of a recirculated cooling water system using a cooling tower. Water is recirculated in the cooling system at the rate of about 10,000 gpm. Nalco corrosion inhibitor No. 32 is used in the recirculated cooling water system. This compound contains no chromium. Acids are added for pH control and chlorine occasionally for algae control.

Boiler water, used at the rate of about 350 gallons per minute, is treated by the hot lime soda process. Phosphates and tannin compounds are used for internal boiler water treatment. City water is used for drinking and sanitary water supplies.

Waste Disposal

The waste effluent of the refinery is conducted from the plant in a 30" sewer to the south toward Yellowstone River. About five hundred feet from the plant the 30 inch line ends; two smaller lines 15" and 18" carry the wastes to the east and south to the river. The two smaller lines do not run parallel but both discharge to a small ditch several hundred feet apart. This ditch also receives the effluent from the sewage treatment plant of the city of Laurel. The combined wastes flow in the ditch for some 200 feet into a shallow side-stream of Yellowstone River. These wastes at normal river flow do not mix with the main body of Yellowstone River for a distance of some two miles below the point where the refinery and city sewers discharge. The point of entrance of the wastes is a few hundred yards downstream from Highway 310 Bridge and the Laurel municipal water intake.

Part of the sanitary sewage is discharged to city sewers and part into four septic tanks. Effluent from these septic tanks passes into the sewers leading to the master oil-water separator.

Caustic liquors are discharged to an open earth pit.

Details of waste control practice and treatment are given in a subsequent section.

Employees

Employees normally total 156 hourly workers and 25 supervisory and office personnel.

WASTE SOURCES, VOLUME, AND CHARACTER

A description of the refinery processes sufficient to define the waste sources is given in the following section. The cooling water used in indirect heat exchangers or coolers is not discussed for each unit.

A. Primary Distillation

Crude oil is separated into fractions, differentiated by boiling range, in continuous distillation units referred to as crude stills. The major equipment units are the furnace, atmospheric fractionator, vacuum fractionator, and auxiliary equipment such as pumps and heat exchangers. The crude is heated and introduced to the lower section of the atmospheric column. Steam is injected into the column to aid in fractionation. Desired temperatures are maintained in column sections by drawing condensate from the tower, cooling it in heat exchangers and returning it to the tower. Naphtha (gasoline) and gases pass overhead from the tower. Side streams in the gas oil and heavy naphtha range are drawn from the column to strippers. Each side stream when drawn from the tower contains some of the lower boiling materials. To remove these traces and obtain more uniform products each of the side streams is stripped with steam in separate sections of a stripper. The overhead from each stripper re-enters the column. The steam introduced in the stripper and column plus steam created from any water contained in the crude passes overhead with the volatile hydrocarbons to a condenser. The light naphtha and water condense and flow to an accumulating drum. The water and naphtha separate by difference in specific gravity in the drum and the water is drawn off continuously to the sewer by means of a water level controlled valve. Ammonia is added to the crude oil and injected into the fractionating column for corrosion control purposes. This ammonia is absorbed by the water and contained in the water drawoff.

The naphtha from the crude tower goes to stabilizers. The gases go to gas recovery and fractionation operations. The gas oil is sent to the catalytic crackers.

The bottoms from the atmospheric fractionating column are heated and enter the vacuum column. Gas oil is drawn from the vacuum column, mixed with gas oil from the atmospheric column, and charged to the catalytic cracker. Asphalt bottoms from the vacuum unit are further processed for highway construction use or are charged to the thermal cracking unit. The overhead vapors pass through a contact condenser which is reflexed for cooling. Vacuum is maintained with a barometric condenser augmented by steam jet evacuator. The barometric condenser water flows to waste.

Thermal Cracking

Bottoms from the vacuum column plus cycle oil from the catalytic cracking process are fed to the thermal cracking unit. The cracked materials are separated in a flash drum to uncondensed gases, thermal gasoline and residuum. The gases join the gases from the catalytic cracking unit. No steam is injected in the unit and drawoff of water from the products is negligible.

The residuum is fed to a vacuum column when it is desired to produce a low penetration asphalt. Steam is injected into this vacuum fractionator. Vacuum is maintained with a barometric condenser. The steam passes overhead and is condensed by and mixes with the condenser water. The condenser water is part of the recirculated water cooling system and is not discharged to waste.

Catalytic Cracking

The heavy gas oil from the atmospheric column is fed to the fluid catalytic cracking unit. In the catalytic cracking process the gas oil is partially converted to high octane gasoline and gases through the action of heat and pressure in the presence of a silica-alumina catalyst. The products of the cracking unit are fractionated in a column. Two streams, light cycle oil, and heavy cycle oil are drawn from the column. The light cycle oil is drawn to a stripper. Steam is injected into the strippers as well as into the fractionating column. The gasoline, steam, and light hydrocarbons are conducted overhead to a condenser. The light naphtha and water flow to an accumulator where the naphtha and water separate by difference of specific gravity. Water at the rate of 10 gallons per minute is added to the main column overhead condensers for absorption of the ammonia. This water combines with the steam condensate drawn from the accumulator drum. This waste amounts to about 22 gallons per minute and is one of the most significant of the plant because it contains relatively high concentrations of phenols.

The gases leaving the overhead condenser are compressed and cooled. The liquified portion is combined with the catalytic cracked naphtha from the accumulating drum and the uncondensed portion is conducted to the gas fractionation and recovery operations.

Naphtha Stabilization Gas Recovery and Fractionation, and Polymerization

Naphtha from the primary distillation unit, the light naphtha from the catalytic cracking plant fractionator and thermal cracked naphtha are each fed to stabilizer units which remove the highly volatile hydrocarbons, propane and lighter oils from the naphtha. Following such stabilization the naphthas are sent to the sweetening operations.

The uncondensed gases from the primary distillation and cracking units are piped to a gas recovery and fractionation unit which recovers butane and propane fractions from the lighter gases. A water of 3 gpm is given the gases for ammonia removal and reduction of corrosive materials. This water is wasted to the sewer.

The butane and propane fraction of the gases (which contain olefins such as propylene and butylene) are fed to the polymerization unit. The polymerization unit is a hydrocarbon rebuilding process employing a phosphoric acid catalyst which forms high quality gasoline from the feed gases.

The feed gases to the polymerization unit are treated in three steps. The gases are first water washed to remove ammonia, nitrogen bases consisting principally of various amines and substituted ammonia compounds, and part of the H_2S. These compounds poison the catalyst of the polymerization plant if permitted to remain in the gases. The gases are next treated by the Gerbitol process in which they are contacted with diethanolamine (DEA) to remove H_2S thereby protecting the catalyst and preventing conversion of H_2S into highly undesirable mercaptans in the polymerization unit. The sulfides are subsequently removed from the diethanolamine solution and vented to the gas incinerator and burned. The regenerated solution is recirculated. Following the DEA treatment the gases are scrubbed with caustic solution in order to remove mercaptans and traces of H_2S. Wastes from this operation are the wash water and spent caustic. The caustic used in the wash becomes spent in use and is periodically replaced.

The products of the polymerization plant are fractionated into polymer gasoline, butane, propane, and lighter gases. The propane is given a caustic wash. A small amount of spent caustic is periodically discarded from propane washing.

The polymerization catalyst becomes fouled and is replaced at infrequent intervals. This spent catalyst is disposed of to a dump.

Sweetening Operations

Sweetening refers to the removal of H_2S and mercaptans from the refinery products. Several methods are employed at this refinery for different products.

Gasoline from the primary distillation unit (straightrun gasoline) is sweetened by the Hoover process of the Linde Air Products Company. Hydrogen sulfide is first removed by two stage caustic washes. The caustic from the first stage when largely converted to Na_2S solution is used in an after-wash later in the process. Caustic from the second stage is reused in the first stage. Caustic supplied the unit is that which was first used for sweetening of thermal cracked gasoline as explained later. The next step in treatment is contact of the gasoline with a slurry of copper chloride crystals and attapulgus clay. The copper chloride oxidizes the mercaptans to disulfides and is itself reduced to the cuprous state. The solution is aerated which reoxidizes the copper chloride. Copper traces are removed by a water wash and a sodium sulfide after-wash and another water wash in that sequence. The sodium sulfide solution used for the after-wash is the spent caustic from the first step in the treatment. The last step in the treatment is passage of the gasoline through a rock salt filter (NaCl) for the purpose of removing water traces. Finally a metal deactivator removes traces of copper from the gasoline.

Wastes from this operation include the spent Na_2S solution, water washes, and brine.

Thermal cracked gasoline is treated in a similar manner in an entirely separate unit. The first step in this sweetening operation is treatment with 20° Baume caustic for removal of hydrogen sulfide and phenols. When the phenol concentration builds up to 14% the spent caustic is diverted to the flue gas caustic neutralizer. The second step consists of contacting the gasoline with 25° Baume caustic for removal of mercaptans. This caustic when spent is regenerated by steam stripping and the steam and mercaptans are fed to the incinerator. This regenerated caustic is then used to supply makeup to the first caustic wash and to the caustic wash of primary distillation unit gasoline.

The remaining copper chloride slurry treatment and after-washes are the same as described for straight-run gasoline. Following the last water wash the gasoline passes through a sand tower to remove moisture. Wastes from this plant include the spent caustic (which is subsequently used in a straight-run gasoline treatment), spent Na_2S solution, and water washes.

The gasoline from the catalytic cracking plant and polymerization plant are combined for sweetening. Treatment consists of a two-stage caustic wash for removing phenols and sulfides. The first stage caustic is discarded to a flue gas neutralizer when the phenol concentration reaches 40 percent. Caustic from the second wash is returned to the first stage treatment provided its phenol content is not excessive, otherwise it is pumped to the flue gas caustic neutralizer.

127-A

There is no water wash of this gasoline. Phenolic compounds that carry over into the gasoline are stabilized by the inhibitor. Wastes from this unit are the spent caustics.

No. 1 heating oil is doctor treated in a continuous system. This treatment converts the odorous mercaptans to disulfides by reaction with alkaline sodium plumbite solution (Na_2PbO_2) containing a little elemental sulfur. The doctor solution is repeatedly regenerated by heat and aeration and reused. The doctor solution becomes contaminated with sulfates, thiosulfates, and organic lead compounds. The spent solution is treated with sodium sulfide, precipitating out the lead; the spent solution is then discarded.

Kerosene is also given doctor treatment in a batch process.

Miscellaneous Wastes

1. Loading Rack Drainage

Some wastes consisting of leaks, spills, and car drainage originate in the loading rack area. Gasoline, heating oils, and diesel oil are the principal products shipped in tank cars. No car cleaning operations are carried out at this plant.

2. Pump Gland Cooling Water and Gland Leaks (Cooling Water Recirculation System Bleed-Off)

Pump glands are cooled by a stream of water which flows through passages surrounding the gland. Frequently some leakage of the hydrocarbon past the packing gland will occur. Such leakage will be contained in the cooling water which flows to the sewer. The water supplied to the pump gland is from the cooling water recirculating system. Solids tend to build up in the recirculated cooling water because of evaporation in the cooling tower. The wasting to the sewer of water used for gland cooling acts as a bleed-off from the recirculated cooling water system. The bleed-off limits the build up of solids in the cooling water. This water will contain chemicals used for corrosion and slime control in the cooling water system as well as any oil leakage into the cooling water from the pump glands or from equipment where the water was previously used. There are also overflow arrangements on both the hot and cold wells of the cooling water system in case insufficient bleed-off does not take place through the cooling glands.

3. Water Treating Wastes

Wastes from water treating consist of water softening sludge and boiler blow-down. These wastes are discharged to an earthen impoundment.

4. Storm Drainage

Storm drainage from paved areas in the refinery goes to the sewers. Rainfall in the area and the nature of the topsoil is such that runoff from the unpaved areas and drainage from the firewalls is not significant.

5. Laboratory and Sampling Wastes

In collecting samples for process and quality control around the plant frequently appreciable hydrocarbons are sewered in drawing long sampling lines to obtain fresh samples. Laboratory wastes from testing these samples may contain significant quantities of hydrocarbons. Pilot-plant research and development work also may be a source of wastes.

6. Wastes at Time of Annual Plant Clean-Up

Normally all units are shut down and cleaned once per year. Units and lines are steamed out or mechanically cleaned and washed. Much of the material washed from the units is iron sulfide. The wash wastes are dark from the sulfide particles.

7. Underpass Drain

The Montana State Highway Department installed a drain a number of years ago from an underpass of the highway under the Northern Pacific Railroad in the city of Laurel to the Yellowstone River. This was reported to be a 16" vitrified tile laid with open joints. The drain flows in a southeasterly direction across refinery property to the Yellowstone River. Much of the time a considerable quantity of ground water enters the pipe along its course and is discharged to the river. The water carries considerable oil contamination which apparently has accumulated from leaks and spills in the refinery area in the past.

WATER POLLUTION CONTROL PROGRAM

Measures in Operation

1. Cooling Water Recirculation

The recirculation of much of the cooling water used in the refinery keeps the volume of wastes to a minimum and therefore aids in controlling oil losses and decreases the necessary size of oil-water separators. One major cooling water use which is not recirculated is barometric condenser water from the vacuum column of the primary distillation unit. This water is contaminated with entrained oil and volatile hydrocarbon so is not suitable for inclusion with the other recirculated cooling water.

2. Neutralization of Spent Caustics

Spent caustics used in the sweetening plant, polymerization plant caustic wash, propane caustic wash plus spent doctor solution are neutralized and stripped with hot flue gas in a column. The neutralizer capacity has been increased within the last year by an additional caustic neutralizer so that more complete neutralization was possible. Materials stripped from the caustic (hydrogen sulfide, mercaptans, and phenols) are burned in an incinerator. The liquor, after flue gas stripping, is near neutral. Acid oils (phenols, etc.) are permitted to rise to the surface and are skimmed off and burned in the incinerator. The liquor after neutralization is discharged to an impounding basin.

3. Impoundment of Neutralized Spent Chemical Solutions and Water Treating Sludges

The neutralized caustic solutions, and spent doctor solutions, are discharged to a small pit formed by excavating and building earth embankments. This pit is located to the southwest of the plant. A similar pit located south of the plant has been abondoned for 1-1/2 years but the oil and solutions have not drained away. Apparently the pit floor is sealed. Plans are to pump the oil pit dry and fill it in. The wastes in the new pit have been seeping away since its use was started. When observed the water level in the new pit was approaching the height of the embankment.

The new pit is separated by an earth embankment from an irrigation canal. The pit is higher than the canal so that it seems logical that seepage from the pit would be into the irrigation canal particularly since the water table in the vicinity is high. The irrigating canal was carrying some water when observed. Conceivably water in the canal could be returning to the river at some control station downstream where any excess or unneeded water was diverted from the canal; whether or not such situation existed was not explored at the time of this conference.

Final disposal of this neutralized caustic is highly important because this material contains a high concentration of phenol. Flue gas caustic neutralizers are reported reasonably efficient in removal of sulfur compounds but considerable phenol remains in the neutralized caustic.

Sludge from water treating, sludge from water softening, and boiler blowdown are discharged to another pit from which they seep away.

4. Stripping of Polymerization Plant Feed Water Wash

The polymerization plant feed water wash is passed to a degassing tank for removal of gas and volatile hydrocarbons and then is sewered. The gases from the degassing tank are vented to the atmosphere through a high stack. A part of the flow is recirculated to the polymerization plant feed wash but 20 - 30 gpm is sewered. The degassing operation helps to reduce the ammonia and H_2S which would otherwise be discharged with the wastes.

5. Treatment in Gravity Type Oil-Water Separators

The refinery wastes to be discharged to the river enter a general plant sewer system known as the "hydrocarbon sewer" which discharges to a gravity-type oil water separator. Some overflow from the hot and cold wells of the cooling water recirculating system are discharged to a sewer which by-passes the separator but this flow is ordinarily negligible. The separator effluent and any flow in the by-pass sewer make up the wastes going to Yellowstone River.

The oil-water separator appears to conform to the design recommended by the A.P.I. Waste Disposal Committee during the period 1930 to 1940. The tank is divided into several chambers by means of transverse baffles. The separator is approximately 18' x 65' in plan and has a water depth of 4.5 feet. Based on 1000 gpm flow through this tank, the average velocity would be 1.6 feet per minute and the settling time would be about 40 minutes.

It would appear that the volume of wastes being discharged to the separator may be slightly exceeding the recommended capacity for this unit for obtaining optimum oil removal. The efficacy of the unit should be checked by analyzing the effluent for oil.

Oil recovered by the separator is skimmed and drawn to a slop oil tank where it is heat treated to break emulsions and returned to the plant feed. Solids accumulating in the separator are removed as necessary by means of clam shell dredge. The need for intermittent cleaning of this type separator is one of its principal disadvantages. More recent designs provide for continuous sludge removal by mechanical means.

Two small older separators are available for use during periods of cleaning the large unit. These units are of such capacity as to provide very short detention.

Additional Waste Control Measures Under Way and Planned

1. Stripping of Catalytic Distillate Drum Water Drawoff with Flue Gas

The company proposes in the near future to have in operation a column for stripping the water drawoff from the catalytic cracker distillate drum with hot flue gas. It has been reported that such stripping practice removes only a small part of the phenols present. This waste is probably the most significant of the wastes being discharged to the hydrocarbon sewer from the standpoint of phenol content. The tower for this operation is in existence and piping arrangements are expected to be completed by the spring of 1956.

2. Paving of Tank Car Loading Area

A project is currently under way to pave the tank car loading area with concrete in order to collect the leaks, spills and tank car drainage. They will be drained to the hydrocarbon sewers leading to the oil-water separator. This project will be completed in the spring of 1956. It is hoped that paving this area will reduce the oil in the underpass drain.

SUMMARY OF WASTE SOURCES AND DISPOSAL PRACTICED

In recapitulation a summary of significant process wastes, the sources of which were discussed previously, is listed below, together with information on their disposal and principal objectionable constituents.

Source of Waste	Principal Objectionable Constituents	Disposal (Current Practice)
Water Drawoff from Primary Distillation Unit Naphtha	Phenols, small amount; Ammonia	To hydrocarbon sewer and through oil-water separator to river.
Barometric condenser water from primary distillation unit vacuum column	Oil Mercaptans H_2S	To hydrocarbon sewer and through oil-water separator to river.
Water drawoff from catalytic cracking unit distillate drum	Phenols Ammonia	The waste is discharged to the hydrocarbon sewer and through the oil-water separator to the river.
Water washes following copper sweetening of straight run gasoline	Phenols, small amount	To hydrocarbon sewer and through oil-water separator to river.
Water washes following copper sweetening of thermally cracked gasoline	Phenols	To hydrocarbon sewer and through oil-water separator to river.
Loading rack drainage	Oil	To hydrocarbon sewer and through oil-water separator to river.
Pump gland cooling water	Oil	To hydrocarbon sewer and through oil-water separator to river.
Sampling wastes	Oil	To hydrocarbon sewer and through oil-water separator to river.
Polymerization plant feed wash	Ammonia Nitrogen Bases H_2S	Passes through degassing tank and discharged to hydrocarbon sewer, thence through oil-water separator to river.
Spent caustic solutions and spent doctor sollutions from sweetening operations, polymerization plant feed wash, and propane wash	Phenols Sulfides Mercaptans Caustic	Neutralized and stripped with flue gas. Neutralized solutions discharged to an earth impoundment.

SUPPLEMENT TO WASTE CONTROL EVALUATION REPORT FROM INFORMATION OBTAINED IN JUNE OF 1956

In review of this memorandum by the Farmers Union Central Exchange additional information was presented. This new information included changes in the plant and reports on accomplishments in the program of instituting additional waste control measures since the October 1955 conference. The new information is presented in this supplement under headings corresponding to the original memoranda.

Capacity

The program to increase capacity was completed in May of 1956 and the new rate of refining crude as of June 1956 was about 18,000 barrels per onstream day.

REFINERY OPERATIONS, FACILITIES, AND PRODUCTION

Waste Disposal

The open ditch which received the refinery and municipal sewage plant effluents was redirected subsequent to the November 1955 observations and now the flow is into swifter currents in the stream.

Oil sludge is no longer discharged to an open earth pit.

WATER POLLUTION CONTROL PROGRAM

Waste Control Measures in Effect Since October Conference

1. Stripping of Catalytic Distillate

Drum Water Drawoff with Flue Gas

A portion of this water, that from the main column receiver is passed through a column where it is neutralized and stripped using flue gases. The remaining portion of water drawoff is sewered. It has been reported that such stripping practice removes only a small part of the phenols present. This waste is probably the most significant of the wastes being discharged to the hydrocarbon sewer from the standpoint of phenol content.

2. Paving of Tank Car Loading Area

At a cost of $60,000 the entire loading rack area was paved with concrete and drains were installed to conduct the drainage to the oil-water separator. No oil is now drained or spilled on the ground.

3. Replacement of Underpass Drain

The drain from an underpass of the highway under the Northern Pacific Railroad in the city of Laurel to the Yellowstone River was replaced using Armco galvanized pipe with mechanical joints for a distance of 3000 feet across the refinery property and about 1000 feet north of the refinery.

This installation was completed May 26, 1956. This measure should prevent infiltration of oil contaminated ground water into this drain.

4. Sale of Spent Caustic from the Caustic Treating of Catalytically Cracked and Poly Gasolines

The spent caustic from this operation which contains a considerable concentration of phenols, cresols, and sulphides is being stored and will be shipped in tank car lots to another plant where it will be processed for phenol recovery.

ADDITIONAL PLANNED WASTE CONTROL MEASURES

1. Diversion of Wash Water from Washing Light Gases to Neutralizer

This wash water amounting to about 3 gallons per minute will be diverted to the waste water neutralization and stripping column as soon as the latter unit has achieved efficient operation.

2. Concentration and Sale of Caustic Solution from Thermally Cracked Gasoline Sweetening

Consideration is being given to concentration of phenols in this caustic solution so that the material will be accepted by the same company processing the spent caustics from catalytic gas treating.

/Sgd/ G. N. McDermott
Sanitary Engineer
Industrial Wastes Studies
WS and WPC Research
Robert A. Taft Sanitary
Engineering Center

APPROVED:

/Sgd/ Glen J. Hopkins
Sanitary Engineer Director

This installation was completed May 26, 1956. This measure should prevent infiltration of oil contaminated ground water into this drain.

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/Sgd/ Glen J. Hopkins
Sanitary Engineer Director

YELLOWSTONE RIVER SURVEY
AS
RELATED TO FARMERS UNION CENTRAL EXCHANGE PETROLEUM REFINERY
LAUREL, MONTANA

A comprehensive study of waste discharges to the Yellowstone River from above Laurel to below Sidney, and to the Big Horn River from above Hardin to its confluence with the Yellowstone, was made during the period November 7 to 13, 1955.

Wastes discharged to the Yellowstone River by this Refinery consist of the effluent of the separators, wastes infiltrating into the Highway Underpass Drain, and probably certain wastes infiltrating to the slough and surface canals in and bordering the refinery area to the south. The separator outlet conduit divides, one line discharging to an open ditch in the city dump area and the other through an abandoned separator to an open channel. The flow through the city dump subdivides with part going direct to the river. The remainder flows downstream and joins flow from the abandoned separator. These wastes and the effluent from the Laurel municipal treatment plan flow into a slough along the north bank of theriver. The upper end of the slough was cut off from the main flow at the time of the study. An approximate six-inch raise in the river does, however, cause flow through the slough.

Industry reports that subsequent to the study refinery wastes have been redirected so all flow goes direct to the river.

Twelve grab samples, collected at 2-hour intervals from approximately 3:00 p.m. on November 8 to 1:00 p.m., November 9, from the separator effluent, were composited according to flow. Rates of flow were calculated from a rectangular weir constructed in the control manhole at the separator outlets.

Total 24-hour flow was calculated as 750,000 gallons. The pH of the waste varied from a maximum of 8.4 to a minimum of 7.4 for an average of 7.9.

Oxygen consumed was 294.7 parts per million (ppm), indicative of an average strength of chemical oxygen demand. This analysis is a measure of the oxygen required to stabilize wastes chemically. The 5-day 20° C. biochemical oxygen demand of the waste was 181 ppm, giving a total of 1,130 pounds for the period. This is equivalent organically to the domestic sewage from 6,780 people.

Suspended solids content was 76 ppm. A phenol concentration of 936 parts per billion (ppb) is high, although amounting to only 5.85 pounds. The 15.6 pounds discharged via the underpass grain, plus phenols contained in the waste stream are in total quite significant.

Copper and lead were found in the wastes, but in amounts considered not to be critical at this time. Metallic wastes are toxic in low concentrations and should be kept under constant surveillance.

Oil determinations were not made but discharge of considerable amounts of oil was evident on and along the river from the underpass drain to well below the municipal sewage treatment plant outlet.

Dissolved oxygen in the Yellowstone River approached saturation during the week of study, and was depressed only at isolated points. Other effects of heavy organic loads on the Yellowstone River were readily visible, however.

Phenols were found at all points in the river, with the heaviest concentrations in the reaches above the junction with the Big Horn River.

Discussion

Phenols and related compounds have been under close scrutiny in the Yellowstone River due to taste and odor problems at downstream public water supplies. Presence of phenolic compounds in the river has been demonstrated by previous work of the Montana State Board of Health. Cyclic developments of tastes and odors during the fall and winter months is highly indicative of phenolic compounds in combination with other organic wastes. Low river temperatures materially reduce the rate of biological destruction of phenols, making the problems more acute in winter months. Synergetic action of organic wastes discharged in large amounts from other sources, particularly in the fall of the year, may also be a factor.

Other factors which may intensify the objectionable effects of phenols are: variations in production at the numerous industries; spills, accidental or otherwise; toxic materials as heavy metals, in sufficient concentration to produce inhibiting effects; and raising and lowering of the river level, thereby flushing out observed impoundments or sludge deposits. Oils in waste effluents may also be a factor.

Recommendations

It is recommended that:

1. Paving of the loading rack area be completed.
   Industry has reported this as completed since the study.

2. Spent caustics and waste phenols be disposed of other than in a pervious area.

3. A thorough study be made of each individual source of waste within the plant to delineate and evaluate sources of phenols, oils, caustic, and acid.

4. Phenols and related compounds be virtually eliminated from plant wastes. This can be accomplished by reclamation, reduction in losses, and biological treatment for residual wastes. Reduction in the volume of water used may be an important step in the waste control program.

5. All oils be virtually eliminated from plant wastes. Provision for emulsion breaking should be made if necessary.

TABLE 1

YELLOWSTONE RIVER SURVEY
NOVEMBER 1955
FARMERS UNION CENTRAL EXCHANGE PETROLEUM REFINERY
LAUREL, MONTANA

November 8-9

	Underpass Drain	Refinery Effluent
Flow MGD	2.2	0.75
pH		
Average	7.5	7.9
Maximum	7.7	8.4
Minimum	7.4	7.4
Oxygen Consumed ppm	83.0	294.7
B.O.D. 5-Day 20° C.		
ppm	8.0	181.0
Pounds	147.0	1,130.0
Suspended Solids		
ppm	8.0	76.0
Pounds	147.0	474
Phenolic Compounds		
ppb	849	936
Pounds	15.56	5.85
Copper		
ppm	.02	.33
Pounds	.367	2.06
Lead		
ppm	.06	.06
Pounds	1.1	.376
Temperature °C.		
Average	12.3	35.8
Maximum	13.0	39.0
Minimum	12.0	34.0

Production per day
bbls. crude November 8 and 9 - 13,477

6. Acidic or caustic wastes be handled so as to preclude adverse effects on treatment units or the receiving stream.

7. Toxic wastes be withheld or discharged at a controlled release that will reduce the concentration below allowable limits in the river.

8. An effective monitoring and control procedure be established over all plant wastes so none can be released without adequate treatment.

9. Increased attention be given to pollution control during the "turn-around" period.

10. The final waste effluents, after appropriate treatment, be discharged to the main channel of the Yellowstone to take maximum advantage of dilution and preclude accumulation of waste materials in tributary channels. This has reportedly been accomplished since the study.

11. A comprehensive plan for additional pollution control, including a time schedule of installation and construction, be prepared and submitted at the earliest possible date to the Montana State Board of Health for review. As much of the program as possible should be completed prior to the fall of 1956.

/Sgd/ Glen J. Hopkins
Sanitary Engineer Director